CHAPTER 3

BITUMINOUS PAVEMENTS

3-1. Pavement structure

A typical flexible or bituminous pavement structure consists of the following pavement courses: subgrade, subbase, base, and bituminous wearing surface. This section deals with types of bituminous surfaces, types and causes of distress, and methods and materials for repair.

a. Wearing surface. The wearing surface is the uppermost layer of the pavement structure. In a flexible pavement, it is a mixture of bituminous binder material and aggregate. The binder may be sprayed on the surface followed by application of aggregate and referred to as a bituminous surface treatment. The binder and aggregate may be mixed in a central plant or mixed in place on the road and referred to as hot or cold mixes. The wearing surface may range in thickness from less than an inch, as in the case of a surface treatment, to several inches of high-quality paving mixture such as hot-mix AC.

b. Principal functions. The wearing surface has four principal functions: to protect the base from abrasive effects of traffic, to distribute loads to the underlying layers of pavement structure, to prevent surface water from penetrating into the base and subgrade, and to provide a smooth riding surface for traffic.

3-2. Types of bituminous surfaces

Bituminous materials are adaptive to a wide variety of local aggregate. Design procedures include such factors as type, weight, and volume of traffic, climatic conditions, wearing surface aggregate base and subgrade conditions, and availability of materials and funds.

a. Surface treatments. Bituminous surface treatments are used for corrective or preventive maintenance of pavement surfaces or as a wearing surface for low volume roads. The use of these treatments is limited to pavements which are structurally adequate since these treatments add no significant strength to the pavement.

(1) *Rejuvenator.* Rejuvenators are especially developed products which can be used to extend the life of bituminous pavements. These products may be sprayed on the pavement surface by use of a conventional asphalt distributor. The rejuvenators penetrate into the bituminous pavement usually to a depth of 1/4-inch and soften the asphalt binder. The use of rejuvenators also help retain surface fines and reduce cracking in pavements. One disadvantage of rejuvenators is the lowering of the pavement's skid resistance. For this reason, the use of rejuvenators on runways or other high speed pavements must be carefully controlled. When an unacceptably slipper surface results from the application of a rejuvenator, an application of sand may be applied to increase the skid resistance of the pavement surface.

(2) *Fog seal*. A fog seal is a light spray application of asphalt emulsion applied similarly as a rejuvenator. However, the fog seal is not intended to penetrate into the pavement. A fog seal can be used to seal a pavement surface to waterproof and prevent raveling of surface aggregate. Sand may be applied to areas where the fog seal has lowered the pavement's skid resistance below an acceptable level.

(3) *Single- and double-bituminous surface treatments and seal coats.* The purpose of these treatments is to retard pavement raveling and deterioration. They also improve the surface texture and skid resistance and provide a waterproof wear resistance surface. These surface treatments are normally constructed using an emulsified asphalt combined with the required aggregate for the job being constructed.

(4) *Asphalt slurry seal.* A slurry seal is a mixture of slow-setting asphalt emulsion, crushed fine aggregate, mineral filler, and water. The materials are combined in a special portable slurry seal machine to produce a slurry mixture and then applied directly to the pavement surface. This treatment provides an excellent riding surface while sealing the underlying pavement.

(5) *Coal tar seal.* This surface treatment is utilized where the pavement surface is exposed to fuel spillage. The coal tar emulsion seal coats can be applied with or without aggregate depending on requirements. When aggregate is added, this seal can be applied similarly as an asphalt slurry seal.

(6) *Special applications.* Special applications are those treatments which utilize nonbituminous binder materials including any additives used in surface treatments. Epoxy resins and rubber adhesive compounds are examples of nonbituminous binder materials. The additives include the various types of latex rubber additives used in both asphalt slurry seals and coal-tar slurry seals.

b. Hot-mix bituminous surfaces. Hot-mix bituminous concrete is composed of well-graded mineral aggregates, mineral filler, and bituminous material (asphalt cement or tar, depending on the desired mixture). Procedures and criteria for hot-mix bituminous mixtures are in MIlSTD 620A and TM

5-822-8/AFM 88-6, chapter 9. The hot-mix method of preparing bituminous paving mixtures provides a more thorough uniform coating of the aggregates and allows accurate control of the aggregate sizes. This process results in maximum control of mixture quality. This type of surface may receive traffic as soon as the material has cooled to 140 degrees F. Hot-mix paving mixtures will be compacted while sufficiently hot to be workable, since rolling is ineffective after the material has cooled. A well-designed, hot-mix bituminous concrete is suitable for use under all traffic conditions. Hot-mix bituminous concrete mixing temperatures vary with the viscosity grade; for instance, AC-40 requires higher temperatures than AC-5 because of its higher viscosity. Approximate mixing temperatures would range from 240 to 280 degrees F for mixtures with AC-5 to 280 to 300 degrees F for mixtures with AC-40. The hot mix will be compacted (initial rolling) at temperatures ranging from 240 to 300 degrees F depending primarily on the grade of asphalt used. Well-proportioned and compacted hot-mix surfaces containing properly crushed aggregate have a high stability and high resistance to abrasive action of traffic. When obtainable in small quantities, hot-mix material is ideal for patching and pot-hole repair.

c. Cold-laid bituminous surfaces. Cold-laid bituminous pavements are composed of asphalt cement and liquefier (kerosene), liquid asphalt, emulsified asphalt or tar, and a well-graded mineral aggregate. Plant-mix cold-laid bituminous concrete can be produced with little heat. The heat necessary to reduce the aggregate moisture content to 2 percent or less can often be obtained by aeration of the mixture in the air and sun. By varying the amount of liquefier in the asphalt, these mixes can be manufactured to almost any shelf life. They may then be shipped long distances and stockpiled for future use. This material is especially adaptable for maintenance such as patching, and for small jobs where the tonnage does not justify erection of a hot-mix plant. Equipment now commercially available can heat the stockpiled cold mix, a great benefit, allowing its use for patching during cold weather. To get the best results from a cold mix, it should be placed during hot weather and cured to the proper condition for compaction. The equipment can be attached to the tailgate of a dump truck or be self contained on a trailer. Cold mix containing kerosene liquefier is heated in a heat-jacketed pugmill so that it does not come into contact with the flame. The mix can be heated until the volatiles are driven off deleting the need for cure time. Depending on the quality of materials, stability and density can then be achieved as with a hot mix. Suggested gradation and asphalt types for use in producing plant-mix cold-laid bituminous materials are presented in TM 5-822-8/AFM 88-6, chapter 9 and NAVFAC DM-5.

d. Sand asphalt and sand tar surfaces. Sand asphalt and sand tar surfaces are composed of sand and bitumen. (The Air Force does not recommend use of these surfaces at Air Force installations.) Mineral filler is often added to increase the density and stability of the mixture. Asphalt cement, cut-back asphalt, tar, or emulsified asphalt may be used for binder. The mixture may be produced in hot- and cold-mix plants, traveling plants, or with the usually mix-in-place equipment. Sand mix surfaces are fine textured, dense, and relatively impermeable. Their stability and durability depend on the quality and grading of the aggregate, the amount and grade of bituminous binder, and the mixture control during construction. Sand mixes may be used for surfacing roads and streets, and for patching in maintenance work. Sand mixes will not be used in areas subjected to high pressure or hard rubber tires, or truck-type vehicle use.

e. Sheet asphalt surfaces. Sheet asphalt is a refined type of hot sand-asphalt pavement in which the grading and quality of sand and mineral filler are carefully controlled. The percentage of asphalt required is, in general, higher than that used for sand asphalt. Sheet asphalt can be used as an intermediate or surface course and is constructed 1V2 to 2 inches thick. This surface can be used on roads and parking areas, but it is not recommended for airfields.

f. Stone-filled sheet asphalt surfaces. Stone-filled sheet asphalt surfaces are similar to regular sheet asphalt surfaces except for the addition of coarse aggregate passing the 5/8-inch sieve and retained on the No. 8 sieve in varying quantities not exceeding 35 percent. This type of surface is a type of sheet asphalt and gains no stability from a coarse aggregate particle interlock. This surface is used as a surface course constructed 1 1/2 to 2 inches thick and is sometimes called "Topeka Mix."

g. Bituminous penetration macadam. A penetration macadam surface is essentially a course of large, uniform graded aggregate that, after compacting and keying, is bound and filled with alternate applications of a heavy bituminous material and smaller aggregate. Thickness of one course varies from 1 1/2 to 2 1/2 inches. These surfaces are stable and withstand considerable tearing action of traffic. This construction is used also as a binder or base course for plant-mix surfacing.

h. Recycled bituminous surfaces. Recycling of bituminous pavements is recommended as an alternative whenever it is cost effective. Recycling includes any method of construction that reuses the existing pavement materials. Of the three general recycling processes, hot, cold, or surface recycling; surface recycling is utilized most often for maintenance and repair.

(1) *Surface recycling.* Surface recycling involves recycling the wearing surface course. Surface recycling includes the milling operation, heater planer, or rejuvenating, cold milling machine or a heater-scarifier. The recycled material is then mixed with water, and lubricating or binding agent, then placed, and compacted. The lubrication agent usually added to the mix is a rejuvenator with additional asphalt sometimes added. The cold milling machine has several advantages over the heater scarifier: less environmentally objectionable, the milled material generally contains a more satisfactory gradation, the milled surface provides a good skid-resistance trafficable surface, and the cold milling will allow deeper repairs when conditions warrant.

(2) *Cold recycling.* Cold recycling includes partial- or full-depth pavement recycling without the use of heat. Cold recycling normally utilizes a cold milling machine, and the recycled mix can be produced either in place or at a central plant. Asphalt emulsion is normally added to the reclaimed material to produce recycled cold mix.

(3) *Hot recycling.* Hot recycling includes any process in which the reclaimed material is heated to be relaid as a hot mix. The old pavement can be broken up and then crushed to the desired gradation, or more commonly, a cold milling machine is used for removal. These reclaimed materials are mixed with new aggregates and asphalts to produce hot recycled mixture.

i. Porous friction course (PFC). A porous friction surface course (PFS) is an open-graded, free-draining, bituminous mixture used to reduce hydroplaning and, therefore, improve wet traction. The PFC is a plant-mix hot-laid bituminous surface, usually 1/3 to 1 inch thick. The high void content (20 to 30 percent) of this mix accounts of its internal storage capacity of small amounts for water, internal drainage of this water through the PFC, and more importantly, for the pressure relief afforded. The coarse gradation of a PFC provides both a rough surface texture for tire-pavement contact above the water film level and surface drainage channels. Because of its open texture and inherent low stability, a PFC requires a structurally sound underlying pavement.

3-3. Causes of bituminous pavement distress.

Distress can occur in any type of bituminous surface; however, in the lower quality bituminous surfaces (particularly surface treatments and road-mix distresses develop more quickly and must be repaired immediately to avoid larger, more costly repairs, or complete failure. Most surface failures result from movement or failure in the base or subgrade material. Although well designed and constructed bituminous surfaces are somewhat flexible and will not rupture under limited deflection, large repetitive deflections will cause the surface to crack or be displaced. Detailed distress identification criteria can be found in TM 5-826-6/AFR 93-5 for airfields and TM 5-623 and MO 102.5 for vehicular pavements. Table 3-1 lists pavement distresses and suggested maintenance and/or repair procedures. Some of the most common causes of failures are listed in the following paragraphs.

a. Poor drainage. Bituminous surfaces must be properly drained. Adequate surface and subsurface drainage must be provided. Water ponded on the surface caused by depressions or by high shoulders may eventually seep through the surface and either destroy the bond between pavement courses or saturate the underlying structure, causing a loss of strength. Inadequate subsurface drainage will also lead to base and subgrade saturation, resulting in damage to the bituminous surface. Poor drainage, through ponded water, can decrease the skid resistance of pavement surfaces and decrease the effectiveness of porous friction surfaces. A frequent and thorough inspection should be made of all drains to see that they are free of debris and are working as designed. Subsurface drains should be examined to make sure they are working as intended. In areas subject to long hard freezes, the saturation for base and subgrade resulting from poor drainage along with frost action may completely destroy the pavement. In such cases, the water penetrates and accumulates in the foundation layers. During the winter months, the water begins to freeze, forming ice crystals. As the ice lenses grow, the pavement surface beging to heave and crack. When spring thawing occurs, the pavement structure is left swelled, cracked, weak, and supersaturated. Thus, correction of the drainage problem and rebuilding the pavement structure become necessary.

b. Weathering. When bituminous surfaces are placed, the natural elements, air, water, and sun cause weathering or oxidation. Lighter oils are removed, leaving only a hard bitumen residue that is brittle and lacks the binding quality of the original mixture. When severe weathering or oxidation occurs, the surface cracks readily as it flexes under repeated traffic loadings. In addition, weathered surfaces will appear dead or faded during warm weather and are prone to have fine, irregular cracking during cool weather.

Table 3-1. Pavement distress types and maintenance and repair alternatives

						NHR Method					Surface Treatments				
	Distress Type	Crack Seal	Partial Depth Patch	Full Depth Patch	Skin Patch	Pothole Filling	Apply Heat and Roll Sand	Apply Surface Seal Emulsion	Cold Milling	Apply Rejuven-nation	Agre-gate Seal Coat	Apply Slurry Seal	Fuel Resistant Seal or Overlay	Pourous Friction Surface	Notes
1	Alligator cracking		N,H	M,H				L		L					
2	Bleeding						L,N,H								
3	Block cracking	LM,H								L	L,M	L,M			
4	Bumps and sags		M,H	M,H	M,H				M,H						
5	Corrugation		M,H	M,H											
6	Depression		M,H	M,H	M,H										
7	Edge cracking	I,M	M,H	M,H											If predominant, apply shoulder seal, e.g. aggregate seal coat
8	Joint reflective cracking	L,M,H	H												
9	Lane/shoulder drop off														If predominant, level off shoulder and apply aggregate seal coat
10	Longitudinal tranverse cracking	L,M,H	H*					L		L	L,M	L			
11	Patching and utility cut	M	H*	H*											*Replace patch
12	Polished aggregate								M,H		A	A		A	
13	Potholes		L	L,M,H		L,M,H									
14	Railroad crossing			L,M,H											
15	Raveling		H					L,H	M,H	L	M,H	M,H			
16	Rutting		L,M,H	M,H	L,M,H										
17	Shoving		M,H												
18	Slippage cracking	L	M,H												
19	Swell			M,H											
20	Weathering		H					L,N		L	M,H	M,H			
21	Raveling from fuel spills												M,H		
22	Low skid resistance								M,H		L,M,H	L,M,H	M.H		

Note: L - low severity; M - medium severity; H - high severity; A - has only one severity level.

c. Fuel spills. Asphalt surfaces are softened by gasoline, jet fuel, hydraulic fluid, or oil drippings. Usually small quantities of gasoline evaporate quickly (unless prevented from doing so by waste or dirt) and cause little damage to a tight AC surface. Jet fuel and hydraulic fluids do not evaporate quickly and may puddle and seep into the asphalt pavement. Loads applied while the asphalt is softened cause failures in the pavement surface. Continuous drippings of oil may also soften the asphalt enough to cause shoving under traffic. Spillage and drippings can be a severe problem on a porous friction course due to the high void content. This enables the fuel to readily penetrate and disintegrate the surface. In areas where it is anticipated that the pavement will be subjected to fuel and oil spillage, coal-tar or another approved fuel-resistant surface material will be used.

d. Poor maintenance. Poor maintenance procedures result in rapid deterioration in areas where deficiencies occur. Timely and proper maintenance can prevent many distresses from occurring. Table 3-1 gives the possible distresses and the suggested maintenance and repair procedures to follow.

e. Construction deficiencies. Many causes of bituminous surface distresses are related to pavement construction deficiencies and may not appear for some time after the pavement has been constructed. These problems require increased maintenance resulting in higher costs. The most common construction errors are discussed in the following paragraphs.

(1) *Unseasonable operations.* Best results are obtained when bituminous paving or surfacing operations are done during dry and warm weather. Work performed during cold and damp weather is rarely satisfactory. Low temperature chills the bitumen before proper bedding of the aggregate, or compaction of mixture is obtained. Cool, cloudy, damp weather slows the evaporation of the volatile oils in cutback materials and may cause stripping of the aggregate. Applications of a hot course of bituminous material on a cold or damp surface may result in poor bond and low density.

(2) *Inappropriate bituminous materials.* The type of bituminous material to be used is dependent on the type and gradation of aggregate, the climate conditions, the type of volume of traffic, and the type of equipment used for mixing and application. A bituminous material should be selected that is sufficiently flexible during the winter months and stable during the summer months. Guidance for selection is provided in TM 5-822-8/AFM 88-6, chapter 9; and NAVFAC DM-5.

(3) *Aggregate deficiencies.* Poor gradations of aggregate produce unsatisfactory surfaces. Excess fine particles tend to form an unstable mix which is difficult to compact. Excess coarse particles in plant- or road-mixed material produce an open, porous surface which permits moisture to enter and damage pavement. Excessive use of uncrushed materials, especially natural sands, often results in unstable pavements with poor durability. Unsound aggregate wears rapidly or is shattered or displaced under traffic; rapid destruction of surface follows. Aggregates for seal coats and surface treatments which contain excess fine particles (over 5 percent passing the 100 mesh sieve) do not adhere to bituminous material and tend to ravel. Surface treatment aggregates should generally be a one-sized gradation with the larger particles being not more than approximately twice the size of the smaller particles.

(4) *Overheating.* Overheating bitumen reduces or destroys its cementing qualities reducing its ability to bond to aggregate. In hot plant mixes, bitumen may be burned either by direct heat or by overheated aggregate. Overheating the asphalt binder also reduces its flexibility resulting in increased cracking as the mixture ages. Overheating cutback (e.g., fluxed bituminous materials) drives off the lighter oils, leaving a heavier material that cures more rapidly and is difficult to mix.

(5) *Improper mixing.* Mixing must be continued until all particles of the aggregate are completed coated. Mixing equipment must be cleaned during and after operations. Otherwise, lumps of cooled, bituminous mixture can be dropped into succeeding batches or on section of pavements. If proper mixing is not accomplished, the resulting surfaces may be uneven, have fat spots, or suffer raveling.

(6) *Poor proportioning.* Too much or too little bitumen in proportion to aggregate causes fat or lean spots, respectively. The range of bitumen content between the minimum and maximum required is relatively small for dense-graded materials.

(7) *Placement errors.* One common error in placing a surface course is improper preparation of the surface on which it is to be placed. Irregularities should be adjusted and the surface cleaned and primed or tacked before the new material is placed. Neglecting any of these necessary preliminary operations creates an improperly prepared base which cannot be corrected by simply covering with a surface course. Prime material should be allowed to cure before placement of paving mixture. Too much tack or prime can cause a rich pavement and result in shoving and slippage. Improper pressure, clogged nozzles, poor nozzle alignment, or uneven overlapping of sprays result in longitudinal streaks in surface treatments or seal coats. Each time a pressure

Table 3-2. Possible causes and types of imperfections in finished pavements

Insufficient or Non-Uniform Tack Coat	Improperly Cured Prime or Tack Coat	Mixture Too Coarse	Excess Fines in Mixture	Insufficient Asphalt	Excess Asphalt	Improperly Proportioned Mixture	Unsatisfactory Batches in Load	Excess Moisture in Mixture	Mixture Too Hot or Burned	Mixture Too Cold	Poor Spreader Operation	Spreader in Poor Condition	Inadequate Rolling	Over-Rolling	Rolling Mixture When Too Hot	Rolling Mixture When Too Cold	Roller Standing on Hot Pavement	Overweight Rollers	Excessive Moisture in Subsoil	Excessive Prime Coat or Tack Coat	Excessive Hand Raking	Labor Careless of Unskilled	Excessive Segregation in Laying	Operating Finishing Machine Too Fast	**Types of Pavement Imperfections That May Be Encountered In Laying Plant-Mix Paving Mixtures**
					X	X	X													X					**Bleeding**
				X				X	X																**Brown, Dead Appearance**
					X	X	X													X			X		**Rich or Fat Spots**
		X	X			X	X			X	X	X	X	X	X	X					X	X	X	X	**Poor Surface Texture**
X	X	X				X	X			X	X	X	X		X	X	X	X			X	X	X	X	**Rough Uneven Surface**
		X		X		X	X			X	X	X	X			X					X	X	X		**Honeycomb or Raveling**
		X								X	X	X	X		X	X					X	X	X		**Uneven Joints**
			X		X	X				X			X		X	X	X	X				X			**Roller Marks**
X	X		X		X	X	X	X			X	X			X			X			X				**Pushing or Waves**
			X	X		X								X	X		X	X							**Cracking (Many Fine Cracks)**
														X				X	X						**Cracking (Large Long Cracks)**
		X				X				X	X	X		X	X			X							**Rocks Broken by Roller**
		X		X		X			X	X	X	X											X	X	**Tearing of Surface During Laying**
X	X		X		X	X		X		X			X	X		X		X	X	X					**Surface Slipping on Base**

(Courtesy of the Asphalt Institute)

distributor stops, it drips some bituminous material, even when equiped with circulating spray bars. If this bitumen is allowed to accumulate on the pavement surfaces, fat spots or traverse streaks will result. Streaking will produce rough unsightly surfaces that are subject to extensive raveling and pot-hole disintegration. Table 3-2 gives a listing of possible causes and types of imperfections in finished bituminous pavements.

(8) *Laydown.* In spreading plant-mixed materials, it is important to keep the material level in the spreader hopper. Otherwise, segregation of the material will occur. Large aggregates tend to roller flow to either edge of the hopper. This can result in segregation with excess large aggregates at the edges and an excess of fines in the center portion. This segregation will lead to low or non-uniform density throughout the layer. Joints between low density areas of adjoining lanes of plant-mix materials frequently result in longitudinal cracks or dips at the joints. Unless joints are staggered in two-course construction, this fault is magnified. The mixture requires rolling with the proper equipment at the correct stage of cooling or curing to obtain the maximum practical density. Rolling the mix when it has become too stiff results in low density and a correspondingly higher air void content which leaves the pavement susceptible to rapid weathering. An insufficient amount of rolling can have the same effect. Cracking and aggregate raveling caused by increased oxidation will also develop in a low density pavement. Low density pavements can benefit from additional rolling with pneumatic-tired rollers providing the pavement temperatures are high and the tires are inflated to their maximum pressure (minimum of 90 psi). Periodic rolling with pneumatic tires is also often beneficial to any low traffic areas such as runway and taxi-way shoulders and open-storage surfaces.

3-4. Types of bituminous pavement distress

The types of pavement distress detailed in the following paragraphs include cracking and other distresses caused by traffic, climate, and other reasons.

a. Alligator cracks. Alligator cracks are interconnected cracks forming a series of small blocks resembling an alligator skin. The length of the cracked pieces are usually less than 6 inches on the longest side (fig. 3-1). In some cases, alligator cracking is caused by excessive deflection of the surface over unstable subgrade or lower courses of the structure. The unstable support is usually the result of saturation of the bases or subgrade. Although the affected areas in most cases are not large, occurring principally in traffic lanes, occasionally, will cover entire sections of pavements.

b. Bleeding. Bleeding or flushing is the upward movement of the binder material in the pavement creating a film of bituminous material on the surface (fig. 3-2). This condition usually occurs during hot weather and will cause an extremely slippery surface. The most common cause of bleeding is too much asphalt binder in one or more of the pavement courses. This can result from a rich mix, variations in aggregate blending, improperly constructed seal coat, or heavy prime or tack coat. Traffic volume, tire pressure, or load in excess of design quantities can cause over compaction of bituminous layers forcing the binder to the surface. Bleeding caused by trafficking is not normally a problem on airfield pavements due to lower traffic volumes and less channelized traffic. Variations in asphalt content in

Figure 3-1. Alligator cracks.

Figure 3-2. Bleeding.

Figure 3-3. Block cracking.

PFC are not normally critical for airfield pavements for this reason.

c. Block cracking. Block cracking is an interconnected series of cracks that divide the pavement into approximately rectangular pieces. Block cracking is differentiated from alligator cracking by size and by not being load related. The blocks usually range from 1 by 1 foot to 10 by 10 feet (fig. 3-3). The cracking is caused mainly by daily temperature cycling and by shrinkage of the asphalt concrete. This distress is not load related but is usually associated with the asphalt aging and hardening. This usually occurs over an entire pavement of the same history, cross section, and traffic.

d. Bumps and sags. Bumps and sags, respectively, are small, localized, upward and downward displacements of the pavement surface (fig. 3-4). Bumps can be caused by differential heave or settlement over utilities, frost heave, the buildup of material in a crack in combination with loading. Bumps can also be caused by the movement of PCC slabs overlaid with AC where the movement is reflected through the asphalt pavement. Sags are caused by a localized failure of the underlying material resulting in subsidence.

Figure 3-4. Sag in asphalt pavement.

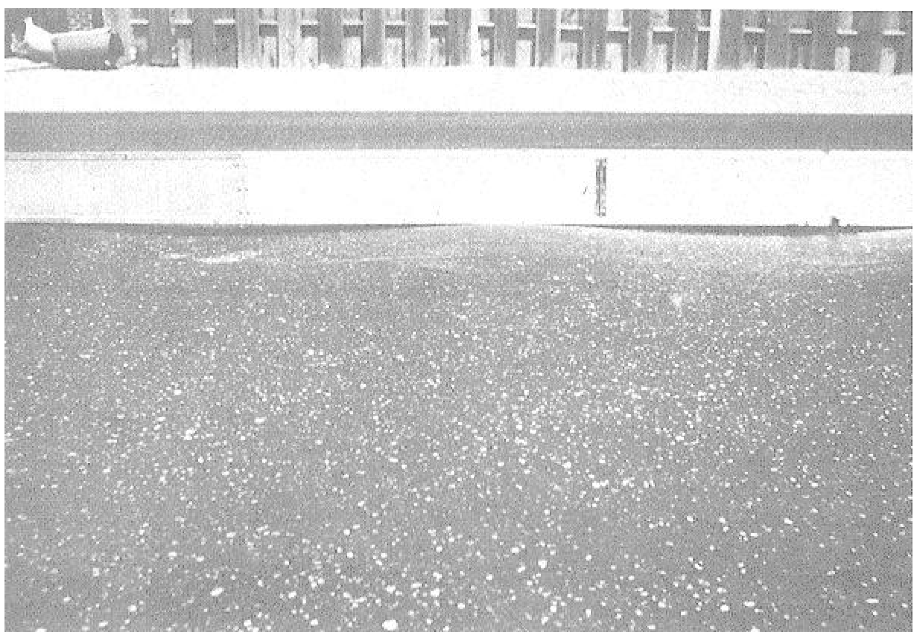

Figure 3-5. Corrugation.

e. Corrugation. Corrugation, sometimes called washboarding, is a form of plastic surface movement typified by ripples across the bituminous pavement surface (fig. 3-5). The cause of corrugations is usually lack of stability in the bituminous mix. Lack of stability can be caused by the mix being rich, the aggregate having excessive amounts of fines, rounded or smooth textured particles, poor bond between material layers, or the use of soft binder.

f. Depressions. Depressions are localized low areas of limited size which may or may not be accompanied by cracking (fig. 3-6). Depressions dip below grade and water collects in them. These "birdbaths" are not only a source of pavement deterioration, but also are a traffic hazard, especially in freezing weather. Depressions may be caused by traffic heavier than that for which the pavement was designed, by settlement of the underlying pavement layers, or by poor construction methods.

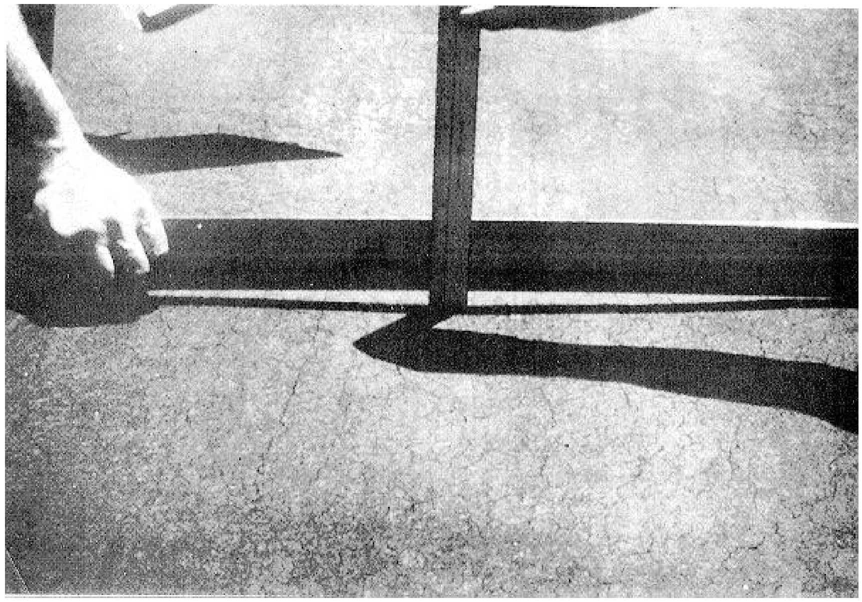

Figure 3-6. Depression.

Figure 3-7. Edge cracking.

g. Edge cracking. Edge cracks are parallel to and usually within 1 to 2 feet of the edge of the pavement (fig. 3-7). This distress is accelerated by traffic loading and is caused by a weakened base or subbase at the pavement edge. Weakening of the base or subbase can normally be associated with a drainage problem causing water intrusion.

h. Joint reflective cracking (from longitudinal and transverse joints) in PCC slabs. Joint reflective cracking distress occurs only on asphalt pavements overlaying PCC pavements (fig. 3-8). These cracks are caused by the moisture- or thermal-induced movement of these slabs under the asphalt pavement. This distress is not load related, although traffic will damage the asphalt pavement at the cracks.

i. Lane/shoulder dropoff. Lane/shoulder dropoff is a difference in elevation between the pavement edge and the shoulder (fig. 3-9). This distress is caused by either shoulder erosion or settlement, or

Figure 3-8. Transverse reflective crack.

Figure 3-9. Lane/shoulder dropoff.

by building up the roadway (i.e., overlay) without correcting the shoulder height.

j. Longitudinal/transverse cracking (non-PCC slab joint reflective). Longitudinal cracks are those which run parallel to the pavement while transverse cracks extend perpendicularly across the pavement (fig. 3-10). This cracking may be caused by poorly constructed paving joints, temperature effects (shrinkage or expansion), hardened or oxidized asphalt, or cracks reflecting up from cracked underlying asphalt layers or stabilized base material.

k. Patching and utility cut. Patching and utility cut patching are areas where the original pavement was removed and replaced with new material (fig. 3-11). These areas are considered defects because the patched area or adjacent area usually does not perform as well as the original pavement.

l. Polished aggregate. Polished aggregate is a term applied to asphalt pavements in which the

Figure 3-10. Transverse crack.

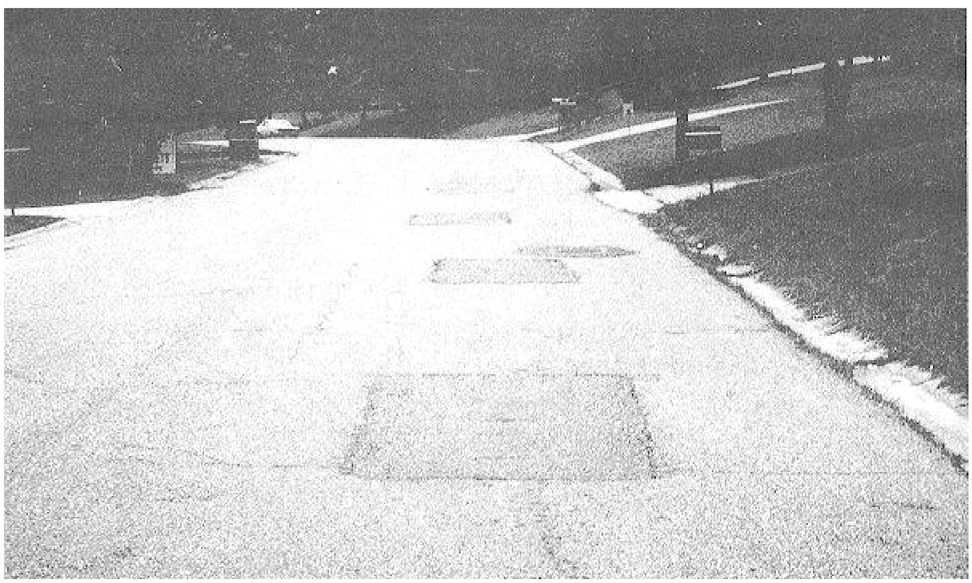

Figure 3-11. Utility cut patching.

surface aggregate has been worn smooth. Polished aggregate causes a reduction in skid resistance, especially when wet (fig. 3-12). This distress is caused by low quality aggregate and repeated traffic applications.

m. Potholes. Potholes are usually caused by a localized weakness in the pavement resulting from a combination of such factors as too little asphalt, thin surface thickness, too many fines, too few fines, or poor drainage (fig. 3-13). Unless repaired promptly, their growth will be accelerated by traffic and moisture collected in the pothole.

n. Railroad crossing. Railroad crossing distresses are depressions or bumps around and/or between the tracks (fig. 3-14).

o. Raveling. Raveling is a progressive separation of the aggregate from the binder (fig. 3-15). Raveling is the failure of bond between the aggregate and the bituminous binder. Raveling may be caused by insufficient compaction during construction, construction

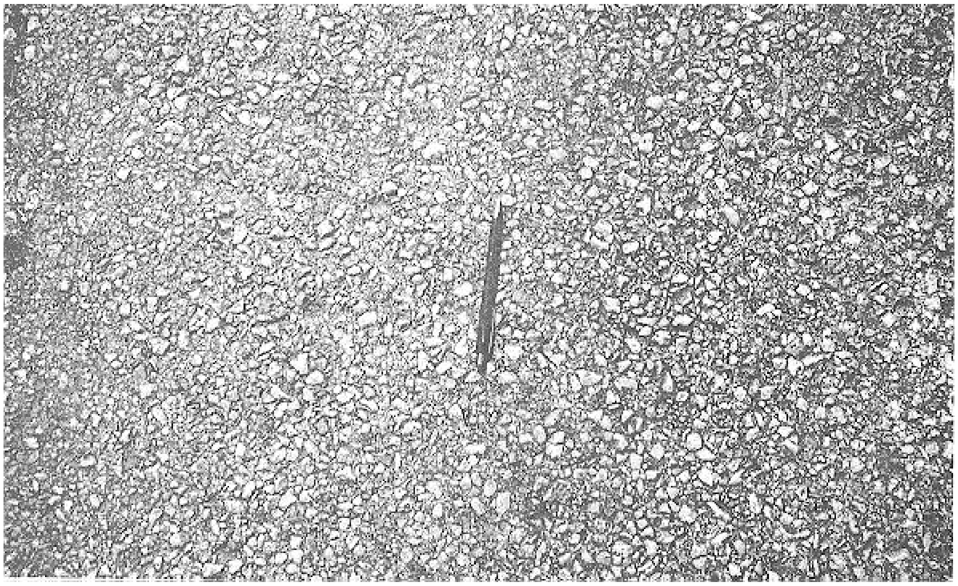

Figure 3-12. Polished aggregate.

Figure 3-13. Potholes.

during wet or cold weather, dirty or disintegrating aggregate, insufficient binder in mix, or over-heating of the surface mix.

p. Rutting. Rutting is a depression in the wheel path (fig. 3-16). In extreme cases there may be uplift between the wheel paths in conjunction with the rutting. Rutting may be caused by a permanent deformation in the pavement layer or the subgrade due to traffic loads. Pavements constructed of low stability AC or unsatisfactory compacted AC are leading causes for the deformation in the pavement layers.

q. Shoving. Shoving is a localized plastic movement in the bituminous surface (fig. 3-17). Areas subjected to frequent vehicular braking action can exhibit shoving. The cause of shoving is usually lack of stability in the bituminous mix. Lack of stability can be caused by the mix being too rich, the aggregate having excessive amounts of fines or rounded or smooth textured particles, poor bond between

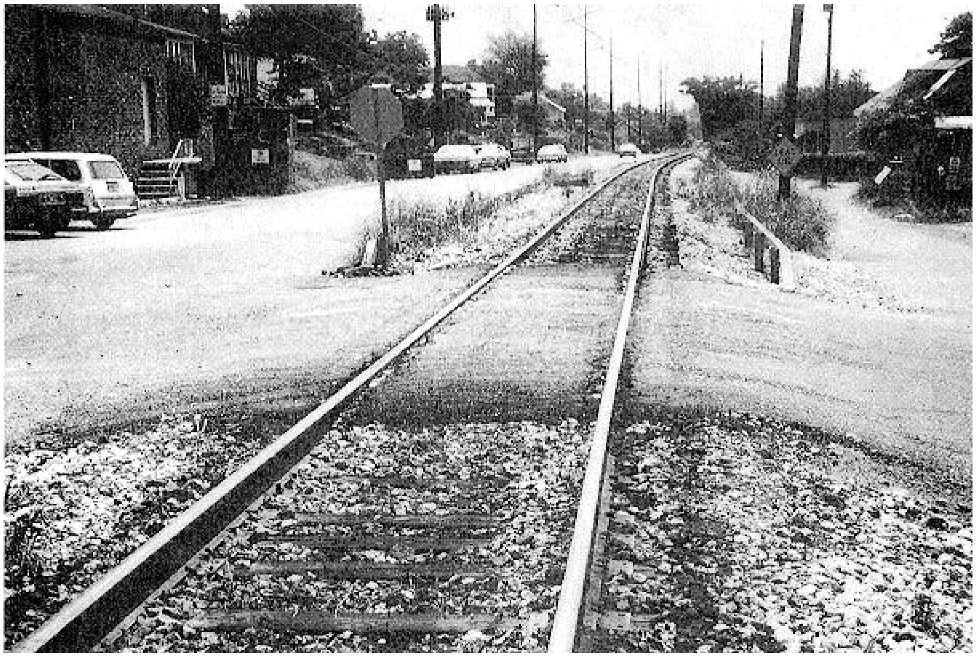

Figure 3-14. Railroad crossing.

Figure 3-15. Raveling.

material layers, or the use of a soft binder. Plastic flow in patching materials can also be caused by excessive moisture in the mix, contamination by oil spillage, or too much volatile material remaining when a cold-laid patch is placed.

r. Slippage cracking. Slippage cracks are usually crescent shaped cracks that normally point in the direction of the thrust of the wheels during braking (fig. 3-18). This distress is caused by a low strength surface mix or a lack of bond between the surface layer and the course beneath. This slippage or delamination can cause failures in PFC under traffic. The slippage can be caused by poor drainage which could aggravate a stripping problem or by construction deficiencies as outlined previously.

s. Swell. Swell is the localized upward displacement of a pavement due to the upheaval of the subgrade or some portion of the pavement structure (fig. 3-19). Swell or frost heave is commonly caused by expansion of freezing water in the lower courses

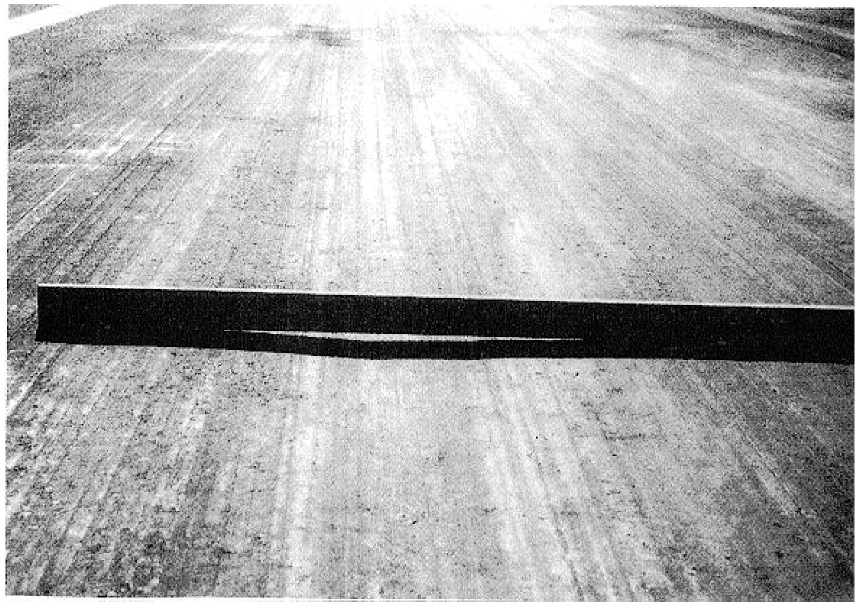

Figure 3-16. Rutting.

Figure 3-17. Showing

of the pavement structure or subgrade. It may also be caused by infiltration of moisture into an expansive-type soil.

t. Weathering. Weathering is a process in which the more volatile parts of the asphalt are lost which results in the hardening or aging of the asphalt binder in a pavement (fig 3-20). Defects such as cracks or holes in the pavement or low pavement density will allow more area of the pavement to be exposed to air and water and increase the weathering process. Raveling is often associated with weathering and is often a direct result of it. Weathering can be a problem in open-graded mixtures such as PFCs due to the increased surface area exposed to weathering conditions.

u. Raveling from fuel spills. Raveling from fuel spills is similar to the raveling described earlier (fig 3-21). However, in this case the raveling is caused by fuel leaching away the asphalt binder. This distress will accelerate if more fuel is spilled on a

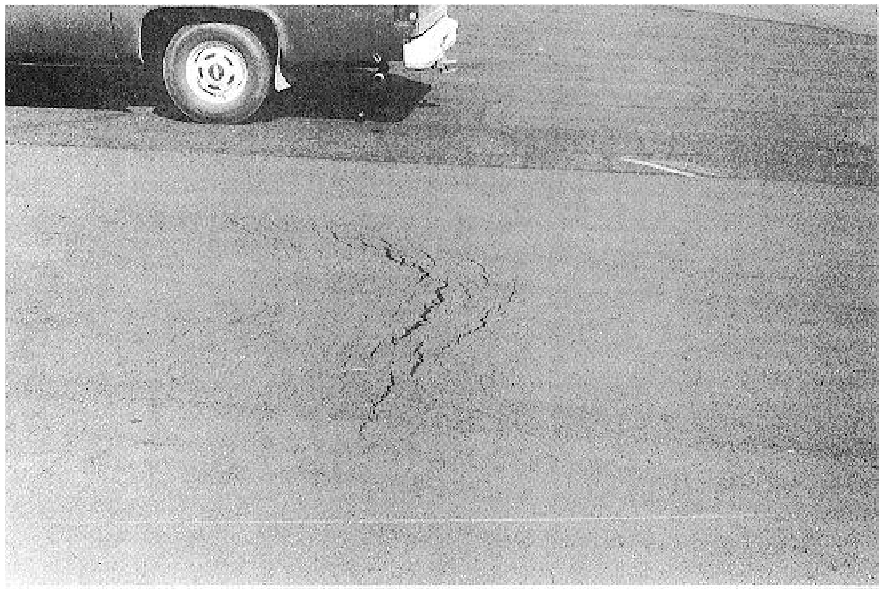

Figure 3-18. Slippage cracks.

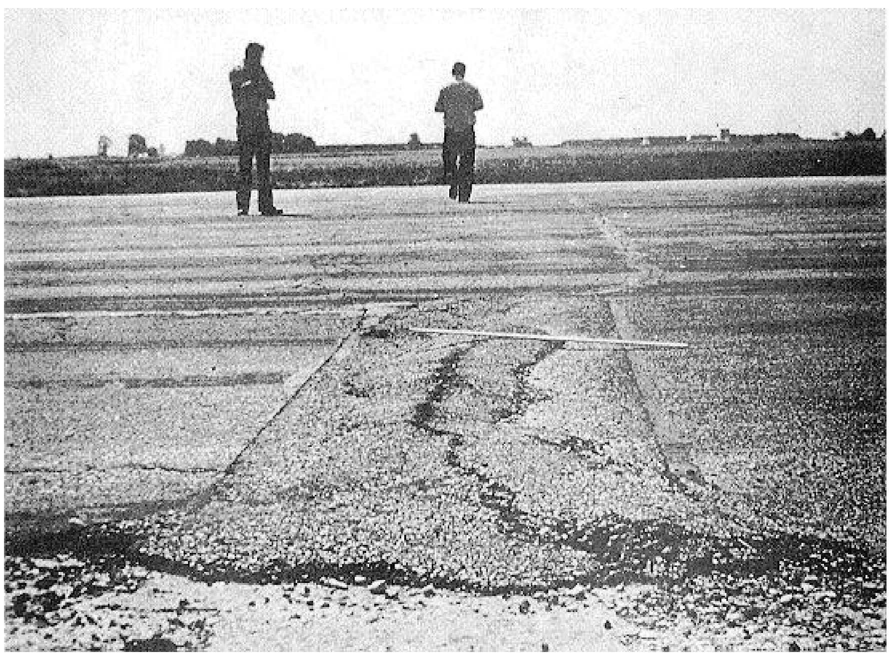

Figure 3-19. Swelling.

surface which had previously started raveling. Fuel spills on PFCs cause distress due to the void space provided in the pavement surface.

v. Low skid resistance. Low skid resistance can be caused by a variety of factors including excessive asphalt binder and the type of aggregate used in the mixtures. The options available to alleviate this distress are to overlay or recycle the pavement, groove the pavement, or apply a surface treatment. When the pavement is structurally sound, the first alternative is unnecessary and the grooving of asphalt pavements may be the best solution (fig 3-22). Surface treatments include seal coats, slurry seals, and PFC.

3-5. Bituminous pavement materials

Materials for maintenance and repair of bituminous surfaces should be equal to or exceed the quality of materials used in initial construction.

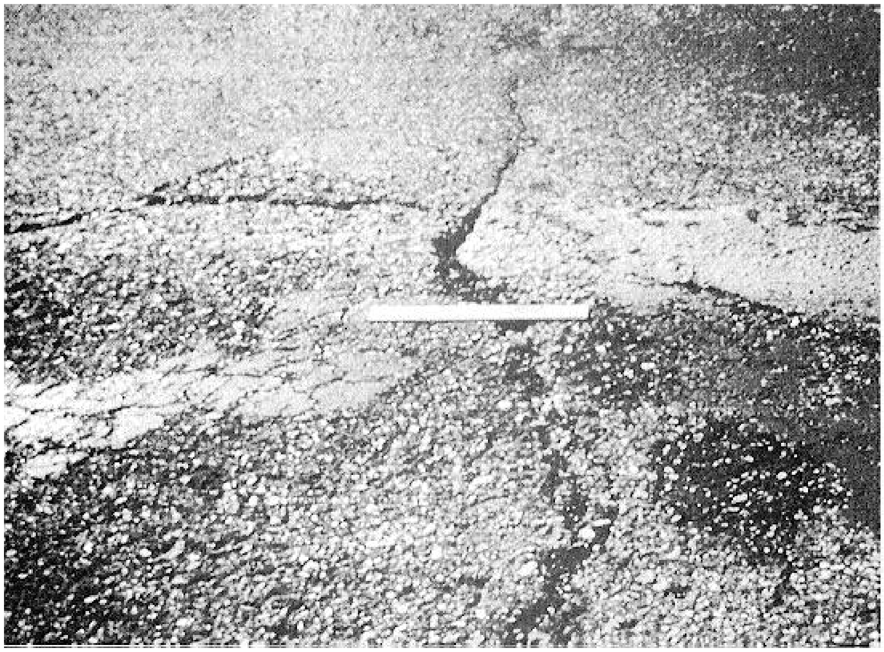

Figure 3-20. Weathering.

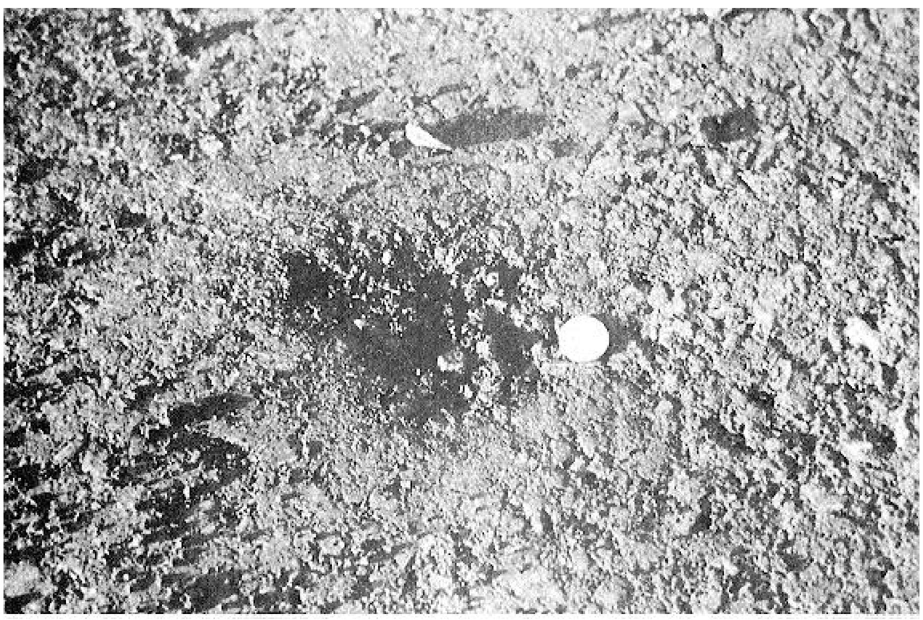

Figure 3-21. Rave

a. Aggregates. A comprehensive survey of the availability of needed aggregate should be conducted, thereby determining local and commercial sources and supplies. Local materials usually require some processing such as crushing, screening, or blending. These will include sand, gravel, and rock that may or may not require any preparation other than screening as well as materials that require both crushing and screening such as limestone and granite. In the vicinity of steel mills, g from fuel spills.

suitable slag aggregate is usually available however, the slag must be seasoned before being used in pavements. Other specialized aggregate types limited to certain localities are often available for use. In some localities, subgrades composed of sand are mixed with bituminous material without adding other aggregates. Aggregate requirements should fit the type of surface involved. For highquality surfaces, suitable aggregate qualities must be specified. For low-cost road-mix surfaces, ag

Figure 3-22. Grooved asphalt concrete pavement.

gregate requirements may be less rigid to minimize costs. Guidance on aggregates is provided in TM 5-822-8/AFM 88-6, chapter 9 and NAVFAC DM-5.

b. Quality. Aggregates must carry the load imposed by traffic and provide the necessary resistance to wear. Aggregates should be hard, tough, durable, and free from an excess of flat, elongated pieces. Aggregates for a PFC must be of high quality with an allowable Los Angeles abrasion loss of 25 percent for airfield pavements and 40 percent for other pavements. Generally, for plant mixes, surface treatments, and seal coats, the aggregates will be clean. In some types of road-mix operations, the use of locally available aggregate such as pit-run gravel containing limited quantities of clay and silt has given good results when combined with the recommended grade of bituminous material. In no case will the aggregate particles be coated with films that prevent the bitumen from coating and sticking since this will reduce the durability of the asphalt mixture.

c. Gradation. Different types of bituminous surfaces require different aggregate gradations. The classifications generally used are dense-graded, open-graded, and uniform-graded aggregate.

(1) *Dense-graded*. The dense-graded group is made up of aggregate, well graded from coarse to fine, which contains an appreciable amount of material passing the No. 200 sieve (dust). The maximum size aggregate normally allowed for AC mixtures is 1 inch (3/4 inch preferred), with the fine aggregate having 3 to 6 percent passing the No. 200 sieve. For a given density, the amount of mineral filler required increases as the size of the coarse aggregate decreases. Graded sands, pit-run sands and gravels, and crusher-run materials are normally required in the higher types of bituminous surfaces because they withstand abrasion well and are water resistant.

(2) *Open-graded*. The open-graded group is made up of poorly graded aggregates and may differ from the densely graded group only in the fines it contains. Open-graded materials have a deficiency of some aggregate sizes between coarse and mineral filler. Densities and voids are almost entirely controlled by the proper amount of fines in the mix design. Open-graded aggregates used in surface courses require a seal coat to provide necessary resistance to moisture and weathering unless designed for a specific purpose (PFCs).

(3) *Uniform-graded*. Uniform-graded aggregate is made up of aggregates of essentially one size. Uniform-graded aggregates are primarily used for surface treatments and macadam courses.

d. *Size limitations*. Aggregate size is usually controlled by the thickness of the course in which it is to be used. For plant-and road-mix types, generally the maximum size is one-half the thickness of the course. In surface treatments, usually aggregate seals and slurry seals, the maximum size aggregate is the thickness of the finished course; for penetration macadam, the maximum size may be two-thirds of the course.

e. *Gradation* specifications. For specifications covering the aggregate quality and gradation for various types of mixes, see TM 5-822-8/AFM 88-6, chapter 9 of NAVFAC DM-5. State specifications concerning aggregate quality and gradation may also be used in selecting aggregates for bituminous surfaces to be placed on roads and streets.

f. Stockpiling. After determining the source of supply, as mentioned earlier, thought should be given to stockpiling the most frequently used aggregate. These stockpiles should be located convenient to work areas and, if possible, be on a clean, hard surface to avoid contamination and make loading easy. On large installations that cover many square miles and have hundreds of miles of roads, streets, and runways, it may be time-saving and economical to have multiple stockpiles located in strategic areas.

g. Handling aggregates. In handling aggregates, the source of supply and method of shipping will determine some of the equipment necessary to economically and adequately move the material from car to stockpile to job. Aggregates may be shipped by rail in ordinary coal cars or in hopper-type coal cars, barges, or trucks. For rail delivery a dragline equiped with clamshell has been used in unloading ordinary coal cars. The hopper-type cars may be unloaded using a portable material conveyer, or by using a front-end loader, with a minimum of preparation at the car dumping site. Specially equipped loaders are currently available that are capable of moving on their own along the top of any type of car for unloading. A clamshell or another type of shovel will be required to unload barges. A medium-sized four-wheel-drive-front-end loader is ideal for keeping stockpiles shaped up, and for loading trucks. Depending on the size of the operation, one or more dump trucks will be available for unloading and hauling materials to the job site. An adequate number of square end shovels and other hand tools should be available for cleanup and for mixing material in small quantities.

h. Asphalt. Asphalt is a dark brown cementitious material, that is solid, semisolid, or liquid in consistency, of which the predominating constituents are bitumens that occur in nature as such as are obtained as residue in refining petroleum.

i. Asphalt cement. Asphalt cement, the basic material of the asphalt family, is refined from crude oil at temperatures below 100 degrees F and is solid or semisolid. To be useful in paving or maintenance operations, it must be fluid enough to coat aggregate. This can be accomplished by heating in a storage tank, asphalt kettle, or pressure distributor, by dissolving in a petroleum solvent (liquid asphalts), and by combining water and an emulsifying agent (emulsion). Asphalt cements have been classified in a number of grades using either the penetration or the viscosity classification. The paving grades of asphalt cements range from a rock-hard (may be powdered) material to a soft flux. The penetration grade asphalts (five grades ranging from 40 to 300) are classified by a standard penetration test. Penetration is determined by measuring the distance a standard needle penetrates the surface of the asphalt sample under specified conditions of time, temperature, and load. Recently, asphalts have been classified by determining the viscosity of the original asphalt and the viscosity of the asphalt after it has been aged in a thin film oven test. Determining viscosity of the original asphalt results in grade classifications ranging from AC 2.5 to AC 40. Determining viscosity of the "aged residue" has resulted in grade classifications ranging from AR 10 to AR 160. Table 3-3 roughly compares the three classifications. The grades listed in the tabulation above will generally cover any combination of climate, traffic, and construction considerations. The temperatures for use of residue graded paving asphalts vary slightly from those recommended for the penetration grade asphalts. See TM 5-822-8/AFM 88-6, chapter 9 or NAVFAC DM-5 for the suggested temperatures. Table 3-4 indicates suggested spraying and mixing temperatures for AR grades. Pugmill mixing temperatures for opengraded mixes will be between 225 and 250 degrees F. To obtain best results, bituminous materials are applied at the temperature ranges prescribed for the various grades. Some grades require no heating when used during hot summer temperatures. Prolonged heating above the temperatures recommended causes loss of volatile materials resulting in increased viscosity. Extreme overheating burns the bituminous material and reduces the binding qualities. Overheating liquid asphalt materials is dangerous because of the highly flammable nature of the distillates. Recommended temperature limits are shown in TM 5-822-8/AFM 88-6, chapter 9 or NAVFAC DM-5. To obtain the best results from maintenance and repair operations, the proper grade of bituminous material must be selected. This selection is affected by such factors as type and gradation of aggregate, weather, and objective and nature of the repairs to be made. In cases where more than one type of bituminous material will give satisfactory results, selection may depend upon the availability and handling experience with the material. In general, light grades are preferable in cold climates and heavy grades in warm climates. Light grades are also appropriate for pavement subject to light traffic. The use of latex rubber modified asphalt binders has been used to improve the performance of PFCs where a tenacious binder is important. Silicon has also been used on the order of 1 ounce per 5,000 gallons of asphalt binder to improve mixing and handling qualities of PFCs.

Table 3-3. Grade classification

Penetration grades	Viscosity grades: AC (original asphalt)	Viscosity grades: AR (aged residue)
200-300	2.5	10
120-150	5	20
85-100	10	40
60-70	20	80
40-50	40	160

Table 3-4. Mixing temperatures

Grade of paving asphalt	Distributor spraying temperature, °F		Pugmill mixing temperature of aggregates, °F	
	Min	Max	Min	Max
AR-160	*	*	300	350
AR-80	295	350	275	325
AR-40	290	350	275	325
AR-20	285	350	275	325
AR-IO	275	325	225	275

*Seldom used for spraying.

j. Liquid asphalts. Asphalt cements which have been softened or liquified by blending with petroleum solvents are generally referred to as liquid or cutback asphalts. When the liquid asphalt is spread on the road or mixed with aggregate, the solvents evaporate leaving the asphalt cement. Liquid asphalts are designated rapid curing (RC) containing a naphthaor gasoline-type solvent. Medium curing (MC) contains a solvent similar to kerosene, and slow curing (SC) contains solvent similar to heavy fuel oil which may be added to an asphalt cement but is often left in during the refining process. The RC, MC, and SC grades are designated as 70, 250, 800, and 3,000 which is based on viscosity rating. A special MC-30 grade, used almost entirely for prime coating and as a dust palliative, is included in the MC group. The grades are designated by the low side of the viscosity range for each grade with the upper viscosity limit being twice the lower value. For example, an RN-70 has a viscosity range of 70-140 centistokes. Each group, RC, MC, and SC, contains the same viscosity grades except for the additional MC-30 grade. In areas with air pollution regulations RC and MC grades may not be available.

k. Emulsified asphalt. Emulsified asphalts are liquid mixtures that contain asphalt cement, water, and an emulsifying agent, which permits the asphalt to remain in dispersion in the water. There are several emulsifiers available including soap, clay, and various salts. Each must be appraised for compatibility, with the asphalt cement being used. Varying the amount and kind of the emulsified agent controls the breaking time or reversion time of the emulsified asphalt to asphalt cement. Emulsified asphalts are graded according to the time required to break or separate from suspension and are categorized as rapid setting, medium setting, and slow setting. Emulsified asphalts are also classified as anionic or cationic. The designations for anionic emulsions are SS, MS, and RS, and the designations for cationic emulsions are CSS, CMS, and CRS. In the anionic type, the globules of asphalt have a negative electrical charge. In the cationic type, the globules are positively charged. These differences in electrical charge improve the coating and bonding properties when used with aggregates of opposite electrical charged surfaces. The choice of a cationic or anionic type is usually based on experience with a particular aggregate. Laboratory testing may be required when utilizing a new source of aggregate. Emulsions are particularly adpated for use during poor weather conditions with damp aggregates when the use of other bituminous materials is prohibited. When temperatures are low, emulsions must be protected to prevent freezing. Freezing causes separation of the water and asphalt rendering the emulsion useless. The letter h in grade SS-1h indicates the base asphalt is somewhat a harder material.

l. *Powdered asphalt*. Powdered asphalt is a pulverized hard asphalt residue which has a penetration of 0 to 5. It is usually shipped in 100-pound bags. It may be combined with a flux or other liquid asphalt product to form an asphalt cement. The ability to handle these materials without heating is often advantageous. Mixed-in-place mixtures with a considerable amount of fine aggregate generally use a low percentage of liquid asphalt for mixing and coating the aggregate. Powdered asphalt can then be incorporated into the mix to produce an asphalt cement of a consistency that could not have been used in the original mixing operation.

m. *Hot mix*. Hot mix should be used for all applicable maintenance and repair work whenever possible. The use of hot mix from local plants will increase the strength and durability of repairs over those constructed with cold mix.

n. *Cold mix*. Cold mix is used extensively for repairs because it can be stored for long periods of time without damage. This mix can be bought and stored in bulk on the base or may be obtained locally in some areas by the truck load. There are commercially available cold mixes that are shipped in bags or barrels and can be used directly. These products make the material easier to handle than bulk materials.

o. *Crack sealers*. Crack sealers are used to seal cracks to prevent water from entering the pavement structure. Narrow cracks are normally sealed with a liquid asphalt while larger cracks are often filled with a sand asphalt mixture.

p. Rejuvenators. Rejunvenators are sprayed onto an asphalt surface and allowed to penetrate into the surface asphalt and soften or rejuvenate it. These materials will normally penetrate from V4 to 3/8 inches into the pavement. These products should only be applied to structurally adequate pavements with relatively high air void content. The use of rejuvenators on high speed pavements is not recommended because it may lower the skid resistance to an unsafe level.

q. Tars. Road tars are produced by the destructive distillation of coal. Road tars are designated RT 1 to RT 12, inclusive, ranging from the low viscosity grade to the high viscosity grade. In addition, there are four other grades of tar designated RTCB-5, RTCB-6, RT-12 Modified, and RT-14. RTCB-5 and RTCB-6 are cutback tars. RT-12 Modified was developed to be used in tar rubber pavements. RT-14 was developed to be used in place of rubberized tar due to the restrictions imposed by Occupational Safety and Health Administration (OSHA) on the production of rubberized tar blends.

r. Storage of materials. All materials, whenever possible, should be stored so as to minimize the effects of climatic condition. Material manufacturers can supply the individual requirements of their particular products.

(1) *Storage of bituminous materials.* The type and quantity of material stored depend upon local conditions. Small quantities are usually stored in drums. Larger quantities, for example over 5,000 gallons of one grade, will be stored in tanks equipped with heater coils. Normally, bituminous storage tanks will be equipped with hot oil or steam coils, unless booster-type unloading equipment is available. Storage tanks will have a circulating system to ensure material uniformity. In cold climates, insulation of permanently installed storage tanks is usually economical. Elevation of tanks to permit gravity loading of distributors is desirable. Storage of large quantities of liquid bituminous materials in drums is not recommended because of the tendency for heavy and light portions of emulsions and liquid asphalts to separate. Drums of liquid bituminous materials will be turned or rolled 180 degrees once a month, or more often, to counteract tendency to separate. Types of stored bituminous material will usually include at least one light grade material suitable for prime coating and a heavier grade suitable for patching or cold mixing. Light and heavy grades of the same material may be mixed in varying proportions to obtain intermediate grades. Heavy liquid materials can also be further diluted by addition of solvent similar to that originally used. Naphtha or gasoline is used for RCs and kerosene for MCs. Emulsions can be thinned by adding water. Material must be warm (minimum application temperature) and stirred continually during mixing or diluting. In cold weather, it is necessary to heat drums to transfer materials into kettles or distributors. One drum at a time may be heated by suspending over the bituminous kettle while material in the kettle is heated. Drums may also be moved into a warm building prior to use or they may be heated in specially prepared structures. Liquid asphalt materials must not be placed near open fires. Buildings where they are heated will be ventilated near the ceiling or roof because gases released during heating are highly inflammable. Tars will not mix with asphalt in drums or containers. Containers must be thoroughly cleaned before changing from tar to asphalt or vice versa.

(2) *Storage of patching mixtures.* In areas near cities, there is usually a commercial plant that produces hot-and cold-mix paving materials. Small quantities of hotand cold-mix bituminous materials may be obtained from these plants at any time. Where these facilities are not available, some form of local cold mixing is necessary. Good cold mixes can be produced with minimum equipment if care is exercised in selecting, processing, and storing materials for the finished product. Many of these coldmix types can be mixed in warm weather, stockpiled, and used several months later.

3-6. Bituminous pavement equipment

There are many different types and models of equipment that can be used for pavement maintenance and repair. The equipment types mentioned below are for general maintenance and repair usually performed on all installations.

a. Cleaning equipment. Motorized vacuum brooms (fig 3-23), circular brooms (fig 3-24), drag brooms, routers, wire brushes, and compressed air are used for cleaning the pavement surface and removing excess aggregate. Cleaning operations are necessary in preparation for seal coating, crack filling, skin patching, and application of slurry seals.

b. Hand tools. Chisels, sledgehammers, shovels, pry bars, and picks are examples of hand tools. Hand tools may be used to make straight, vertical cuts through pavements as well as to break up deteriorated pavement. The use of hand tools is not recommended where other equipment is available because hand operations are time-consuming.

c. *Pouring pots.* Pouring pots are used to pour hot sealing material into previously prepared cracks or joints. The pots hold up to 5 gallons of liquid and dispense the material either from top or bottom spouts.

Figure 3-23. Motorized vacuum broom.

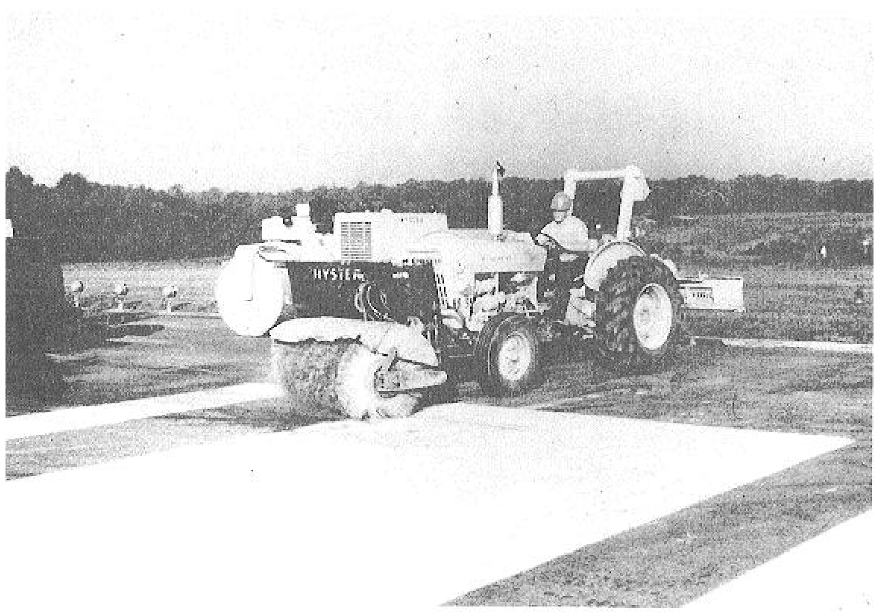

Figure 3-24. Motored circular broom.

d. Squeegees. The squeegee, a U-shaped blade of neoprene rubber attached to a long handle, is used to spread seal coats (fig 3-25) or to force the hot sealing material into cracks or joints. For joint sealing the squeegee is pushed along the crack or joint immediately after it is filled. The blade levels and strikes off any excess material to form a neat and effective crack seal.

e. Power saws. Pavement power saws are usually one-man-operated, dolly-mounted units that have an abrasive circular blade. The saw is either manually pushed or mechanically driven as it cuts through the pavement surface. These saws are capable of cutting a straight line and leaving neat vertical sides. Small portable hand held saws can be useful for repairing small areas (fig 3-26).

f. Cutting disks. Cutting disks are circular, heavy-duty steel plates with a sharpened edge (fig 3-27). The disks are usually attached to a motor grader moldboard or scarifier, or some other piece of

Figure 3-25. Applying a seal coat with squeegees.

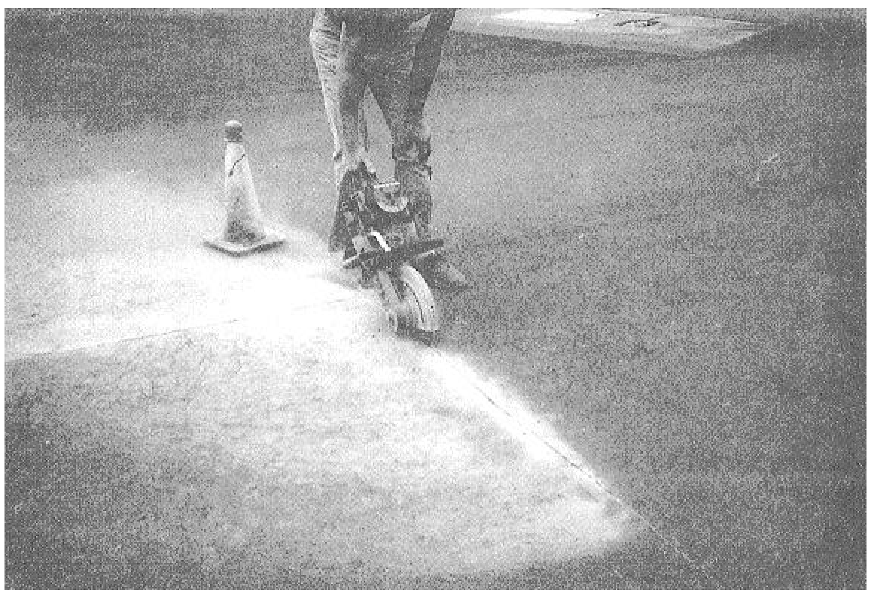

Figure 3-26. Hand held saw.

equipment such as a steel wheel roller. The cutting disk is much faster and cleaner (water is not used) than sawing and is recommended where larger areas of pavement must be removed. It must be noted, however, that the standard cutting disk is limited to approximately 3 inches maximum cutting depth.

g. Jackhammers. Jackhammers with proper chisels are commonly used for cutting and removing pavement surfaces (fig 3-28). When used by a Hand held saw. skilled operator, this tool will produce a straightline cut with fairly vertical sides.

h. Front-end loaders. Front-end loaders are very useful in loading trucks when removing old pavement, transferring patching mixes, or other paving material.

i. Dump trucks. Dumptrucks are used in hauling deteriorated pavement and repair materials to and from the job site. Dump trucks may be end or bottom dump type.

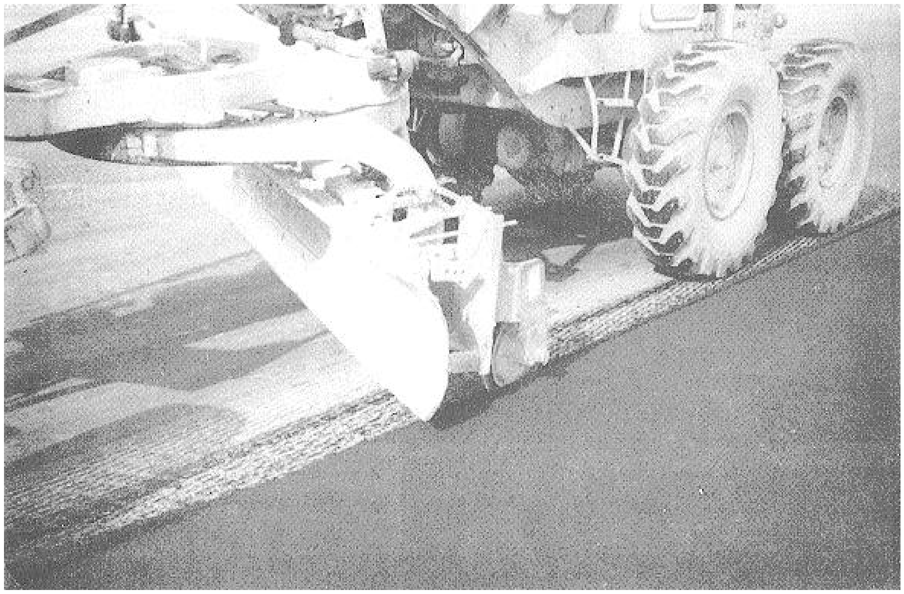

Figure 3-28. Removing damaged pavement with a jackhammer.

j. Propane heaters. Joint and patch propane heaters (fig 3-29) are occasionally used to heat and soften existing bituminous surfaces, thereby improving bonding and aiding in the curing of coldlaid patch materials. When using these devices, care must be taken in order to prevent damage to the pavement due to overheating.

k. Heater scarifiers. Heat scarifier equipment (fig 3-30) heats the pavement surface and then scarifies it to a depth of V2 to 1 inch, depending on the pavement properties (density, aggregate type, etc.). A recycling agent and/or new asphalt is often added to the mix to increase the asphalt content to recommended levels. The scarified mix may be spread and compacted directly (fig 3-31) or it may be combined with new mix before compaction. A preheater is sometimes used to assist in properly heating the pavement before scarifying.

l. Heater remixer Heater remixers (fig 3-32) use a form of infrared or radiant heat to soften the bituminous pavement. After heating, the surface is then scarified to depths of V2 to 2 inches. Separate or preheaters are used when required for greater depth or output. New asphalt binder may be added to the materials prior to compaction.

m. Cold milling machine. Cold milling machines (fig 3-33) are used to correct surface irregularities by milling the surface of the pavement without the use of heat. This equipment consists of a drum equipped with carbide-tipped bits which can cut up to approximately 4 inches of bituminous mix in one pass. The cutting teeth and run speed can be ad-

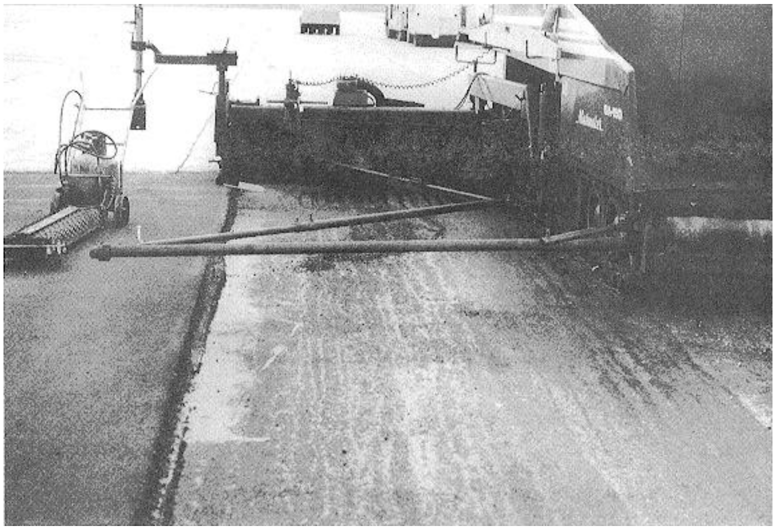

Figure 3-29. Propane joint heater

Figure 3-30. Heater scarifier with blade and spreader attachments.

adjusted to provide the desired surface texture. Some of the equipment has direct control of finished grade by the use of sensors that follow a stringline grade reference. The loose material removed from the pavement surface is usually suitable for use as base or fill material or for recycling into an asphalt base of surface course. Small milling machines for making small cuts such as utility cuts are also available (fig 3-34).

n. Traveling hammer mill. Traveling hammer mills (fig 3-35) are used to breakup pavement surfaces for reconstruction or recycling. The material is usually broken down to pieces less than 2 inches in diameter. The hammer mill is composed of a series of hammer-like appendages which swing about a center drive shaft to strike and breakup the pavement surface (fig 3-36).

o. Pulverizer. A pulverizer is used to break up the pavement into pieces usually less than 1V2 inches in diameter. It can be used in conjunction with the

Figure 3-31. Scarified and bladed bituminous material being immediately respread and compacted.

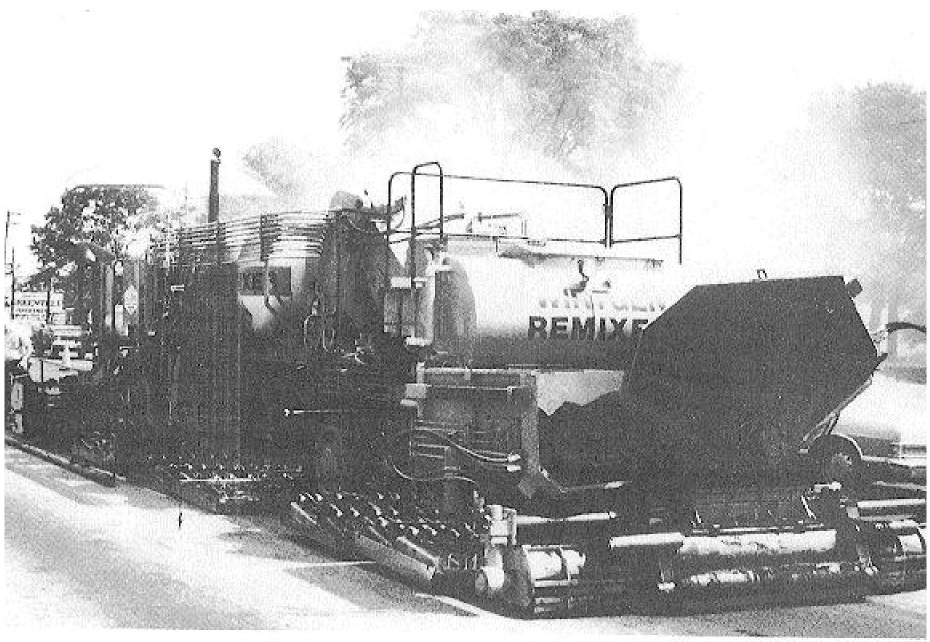

Figure 3-32. Heater remixer for in-place recycling.

traveling hammer mill to further break down the aggregate particles into smaller sizes. It is constructed similar to the hammer mill except that the appendages are more closely packed for finer breakage.

p. Laydown. Small portable hot-mix plants (fig 3-38) are occasionally used to produce hot-mix material at the job site. These units are trailer mounted and consist of a small aggregate dryer, a pugmill, and a bituminous storage tank contained on a single frame. The mix is produced in the same manner as in a stationary plant. The aggregate is fed into the hopper and dried in the dryer. The hot bituminous material is added, and the material is mixed in the pugmill. Because of inaccuracies in job site proportioning of materials, it is difficult to produce a high-quality mix with the portable plant; however, satisfactory patching materials are not too difficult to produce.

q. Stockpile-mix heaters. Stockpile heaters are

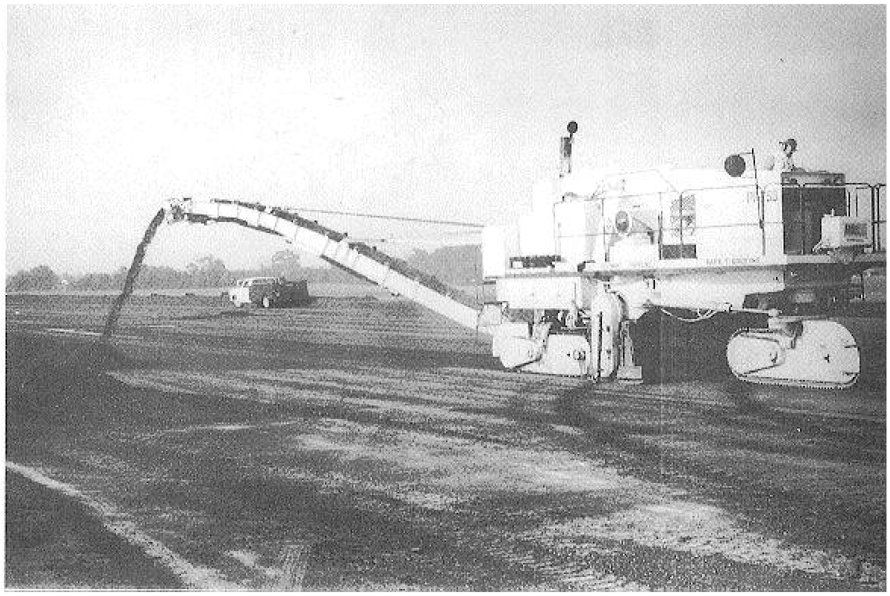

Figure 3-33. Cold milling machine.

Figure 3-34. Self-propelled pavement milling machine.

very convenient for producing small quantities of hot-mix materials that can be hot-laid from stockpiled cold-mix materials. The stockpile-mix heaters can be mounted to the tailgate of a dump truck; larger unit may be trailer-mounted. The unit has facilities for heating and remixing materials. The mixing area is covered and vented to permit safe heating and removal of the remaining volatiles in the cold mix. Units of this kind can be very valuable in a maintenance operation because they make available an economical supply of hot-mix material for emergency repair.

r. Bituminous distributors. Bituminous distributors may either be truck or trailer-mounted (fig 3-39). Each unit is composed of a heater reservoir, a pump, and connecting spray bar. The spray bar is equipped with nozzles especially placed to permit even spraying of closely controlled amounts of liquid

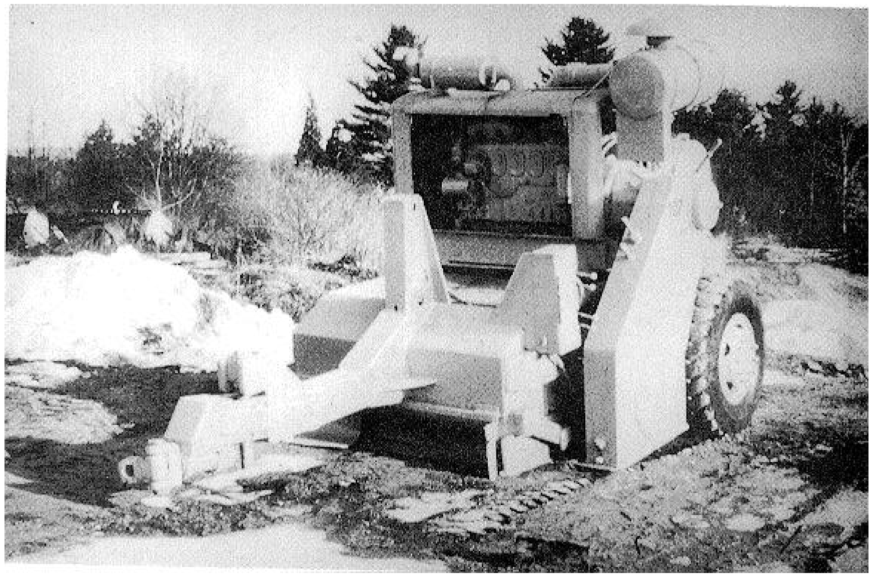

Figure 3-35. Traveling hammer mill.

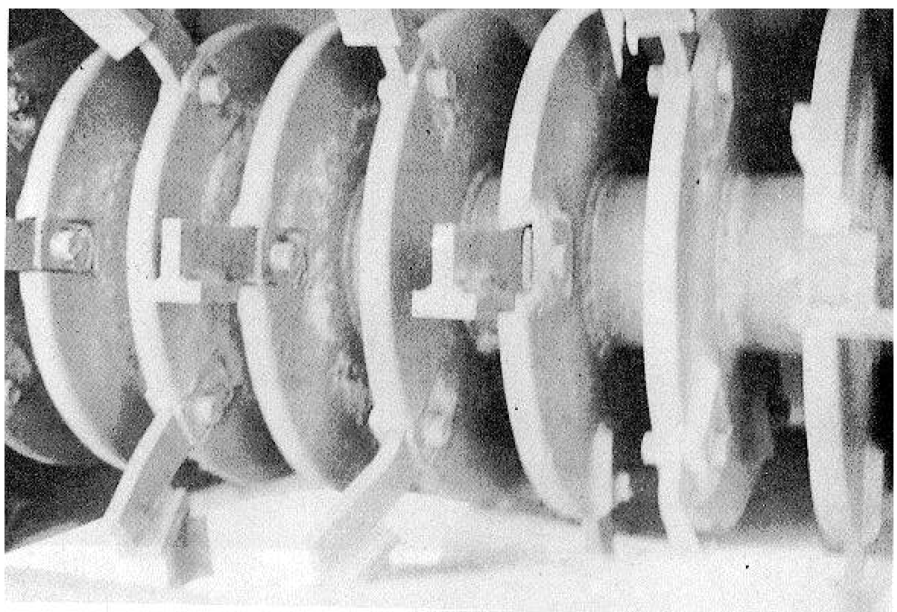

Figure 3-36. Close-up of hammer mill breaking shaft.

bituminous material. The distributor can be used for priming, tacking, and sealing bituminous surfaces.

s. Asphalt kettle. Asphalt kettles are used primarily in repair and maintenance work. They are small trailer-mounted units capable of heating and storing 40 to 500 gallons of bituminous material. A pump mounted on the trailer frame is used to force the liquid bituminous materials through spray nozzles located on the end of a hand-held hose. These units are used for priming and tack coating, in small patchwork, and for crack or surface sealing of bituminous surfaces (fig 3-40).

t. Aggregate spreaders. Aggregate spreaders can be truck-mounted, separate units, or self-propelled (fig 3-41). They are used to evenly spread sand or aggregate. For pavement patching, a tailgate spreader, the most commonly used, is attached to the rear of a dump truck. The rate of application of the aggregate is controlled by adjusting

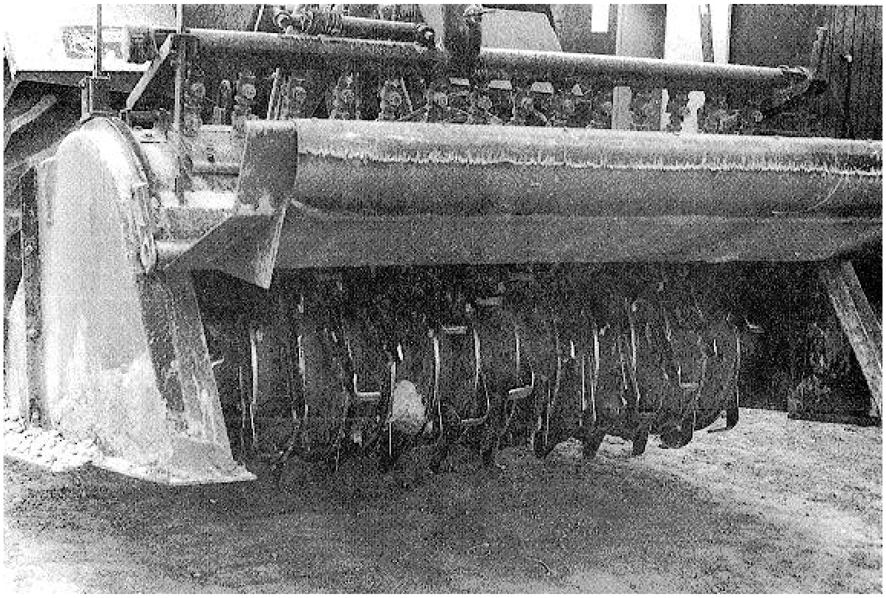

Figure 3-37. Close-up of pulverizer mixing blades.

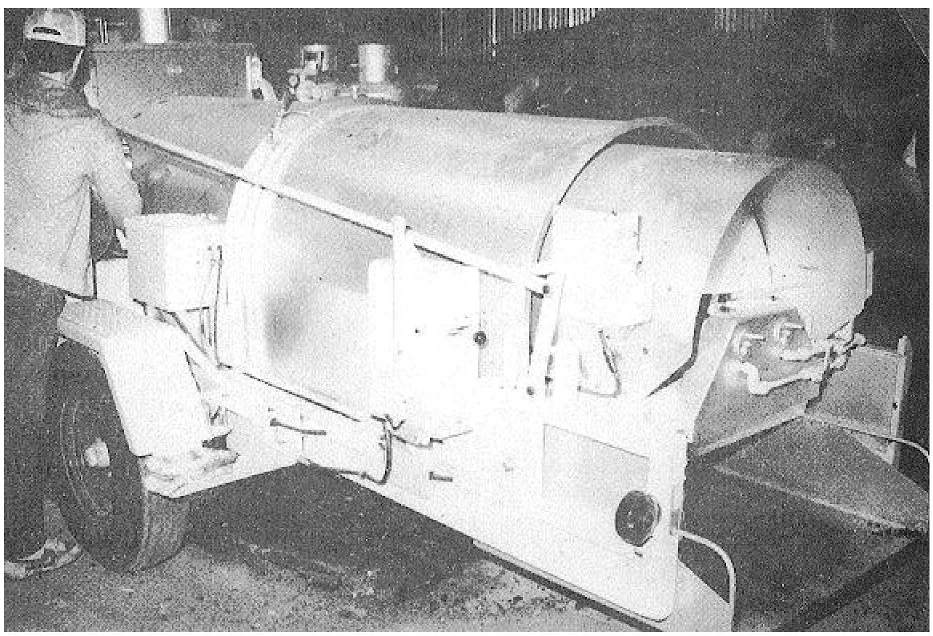

Figure 3-38. Portable hot-mix plant.

the spreader gate opening and auger screws. Spreader boxes and self-propelled spreaders are ordinarily used when large areas of surfacing are involved.

u. Slurry machine. Slurry seal machines (fig 3-42) consist of an aggregate storage bin, emulsion and water storage tanks, a mixing chamber, and a squeegee-type spreader box. Automatically proportioned aggregate, emulsion, and water are deposited in the mixing chamber and thoroughly mixed. After mixing, the slurry is dumped into the spreader box and spread over the areas being sealed.

v. Bituminous paving machine. Bituminous paving machines or spreaders are used in placing bituminous (fig 3-43). These units are equipped with a material hopper, spreader screws, and a strike-off vibrating screen. The spreading widths vary from about 8 to 12 feet. The layer thickness can be varied from approximately 1/2 to 8 inches. The unit may also be used to place untreated aggregate.

Figure 3-39. Bituminous distributor.

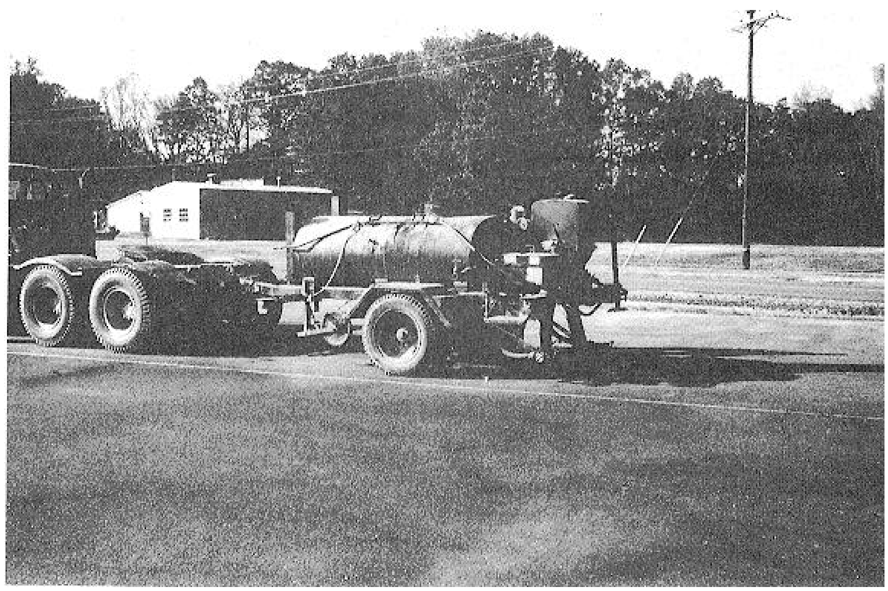

Figure 3-40. Asphalt kettle.

w. Hand tamps. Hand tamps are used to compact very small areas where other compaction devices are difficult or impossible to operate. The hand tamp is constructed by placing a handle on a weighted steel plate approximately 1/4 square foot or less. The tamp is pounded by hand to produce the proper density of a thin lift of soil, aggregate, or bituminous plant-mix. Vibratory plate compactors have engine-driven flat plates that vibrate at high frequency and low amplitude. The unit is usually hand-operated and is used for surface smoothness and density in the top inch of the layer. Frequency range for this equipment is about 2,400 to 3,600 revolutions per minute (fig 3-44).

x. Steel-wheel rollers. Steel-wheel rollers (fig 3-45) are useful in obtaining a smooth compacted surface. They can be used for breakdown rolling or they can be used to remove the marks left by pneumatic rollers. These rollers are not suited for small repairs such as pothole and other small patches.

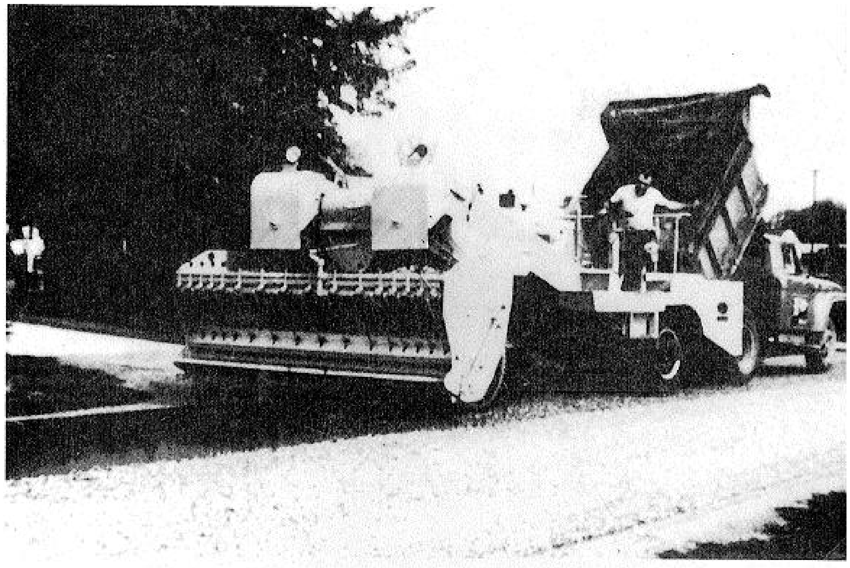

Figure 3-41. Self-propelled aggregate spreader.

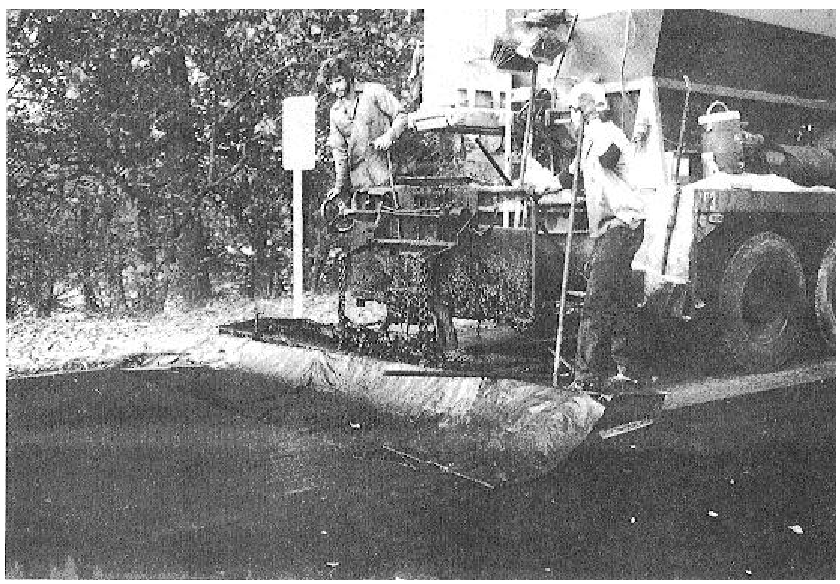

Figure 3-42. Slurry seal machines.

y. Rubber-tired rollers. Rubber-tired rollers (fig 3-46) are used when compacting large area patches. Their wheel action is more effective in obtaining the desired asphalt pavement density and a tight surface.

z. Vibratory steel-wheel rollers. Vibratory steel-wheel rollers (fig 3-47) can be motorized or hand operated and are frequently used for compaction patchwork. The rotation of a high-speed eccentric weight produces a variable frequency and amplitude vibration of the drum that delivers the compaction effort. These rollers are best suited to compaction of granular materials and will produce a smooth, dense surface in bituminous patchwork. Results will be unsatisfactory if improper weight, frequency, or amplitudes are used. Thus, it is essential to have the equipment in proper adjustment for the type of material being compacted.

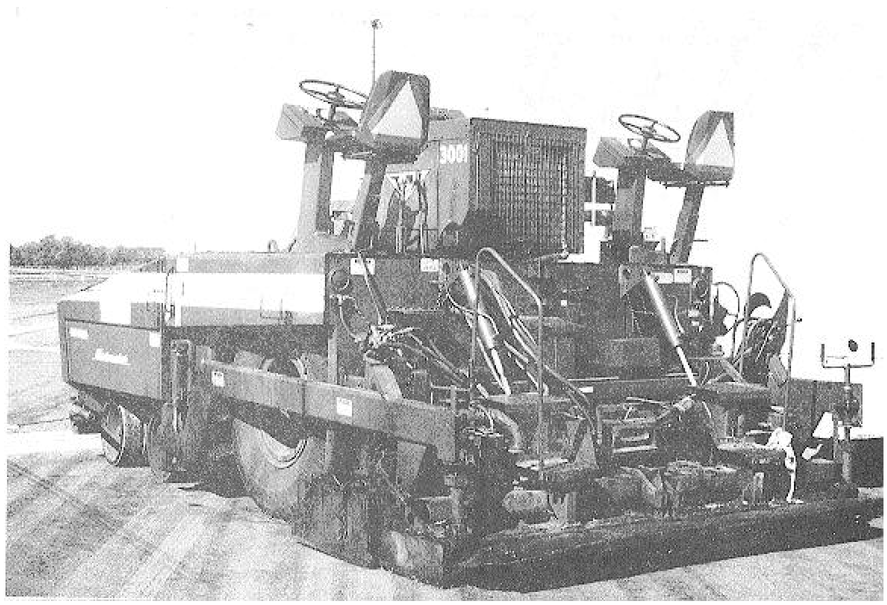

Figure 3-43. Asphalt paving machine.

Figure 3-44. Vibratory plate compactor.

3-7. Bituminous repair methods

Repair methods used will normally be one of the following: crack sealing, skin patches, partial and full depth patches, pothole patching, surface sanding, surface treatments, fuel resistant seals or overlays, or porous friction course.

a. Crack sealing. Crack sealing in bituminous pavements is used to prevent the intrusion of water into the subgrade. Cracks less than V8 inch wide usually can be treated satisfactorily by use of a seal coat. Cracks V8 inch or wider will be filled with a selected joint filler that meet Federal specifications for the type of pavement and service to which the pavement is to be subjected. Large cracks have also been filled successfully with a bituminous sand mixture using a slurry seal mixture or a hot-mix sand asphalt. All joint sealers will be applied at the maximum recommended temperature to ensure good penetration of the crack. Prior to apply joint filler,

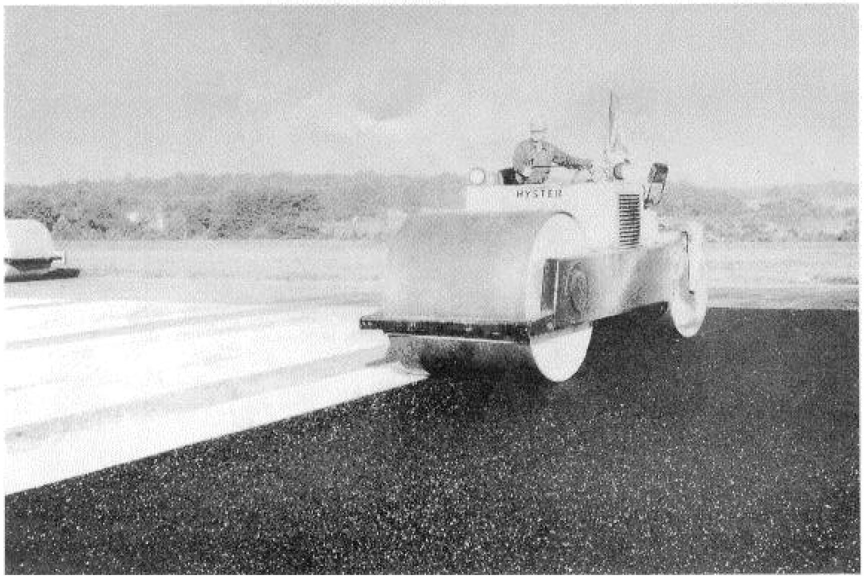

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Figure 3-45. Steel-wheel tandem roller.

Figure 3-46. Rubber-tired roller

the cracks will be routed out and cleaned by use of compressed air so that all loose particles are removed. If experience indicates a compatibility problem with reference to joint sealing material and the pavement, a sand-asphalt mix will be used to seal cracks. Procedures for sealing cracks in bituminous pavements can be found in TM 5-822-11/AFM 88-6, chapter 7.

b. Skin patch. A skin patch is usually placed on the pavement without removing any damaged pavement. A shallow trench with a vertical face is made around the patch to help hold it in place. This is considered a temporary repair.

(1) The area should be cleaned with brooms and, if necessary, compressed air. A tack coat should be applied to the area.

(2) The skin patch should be placed with hot plant mix asphalt or if this material is not available, cold mix may be used. Coarse particles must be removed with a lute in order to feather the edges.

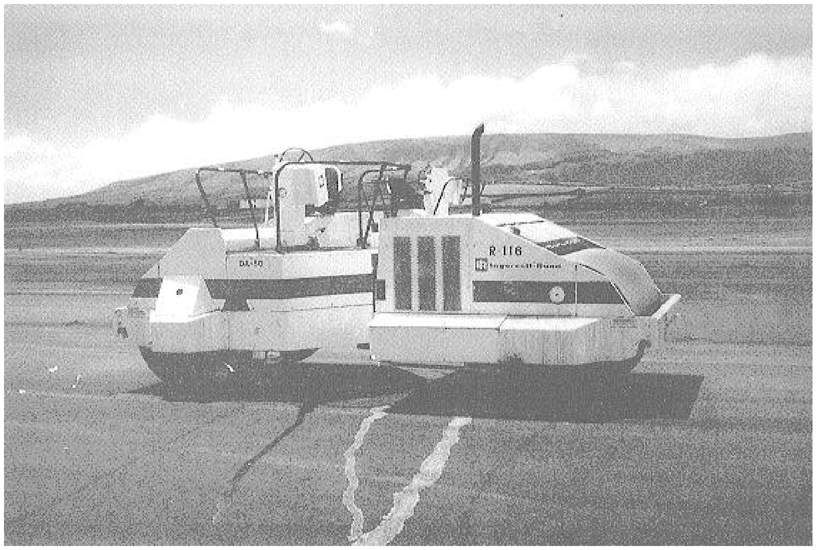

Figure 3-47. Steel-wheel vibratory roller.

(3) This material should be compacted with any available equipment. When necessary, compaction can be accomplished with the wheels of the truck used to transport the mix.

c. Partial-depth patch. A partial-depth patch will extend only as deep as necessary into the pavement to reach undamaged pavement.

(1) The edges of the patch should extend at least 1 foot into satisfactory pavement. The patch should be square or rectangular with vertical edges. The cuts should be made with a circular saw or a jackhammer.

(2) A light coat (0.05 to 0.15 gallon per square yard) of SS-1 or SS-1h asphalt emulsion diluted with equal parts of water should be applied to the cleared area. RC-70 may also be used. Tack coat should be allowed to cure until it becomes tacky to touch (fig 3-48).

(3) If available, enough hot-mix AC material should be spread into depression so that when compacted, it will bring the depression back to the original grade (fig 3-49). If the material has been carefully spread, allowance of approximately 25 to 50 percent overfill should correct for compaction. If edges of patch are feathered, coarse aggregate must be removed from the edges prior to compaction. If plant-mix cold-laid material must be used, it should be aerated as required before it is placed in the depression. Aeration dissipates the solvents and water that may cause an unstable patch. The same overfill for compaction as mentioned above will also be practiced.

(4) After material has been placed, it will be thoroughly compacted using a vibrating plate compactor, roller, or hand tamper. If none of these are available, compaction can be obtained by truck wheels. Surface elevation will be checked by straightedge or string line for grade. If deficient, additional material may be raked into the surface and recompacted. In the repair of deep depressions normally two or more layers of AC are required. The layers should be between 2 to 3 inches for hot mix. Filling the area by following the contour of the depression is sometimes mistakenly done. When this approach is followed, it is nearly impossible to obtain good uniform compaction or match the original pavement grade. The correct way to repair a deep depression is to begin in the deepest part of the depression and place a thin layer, the surface of which, when compacted, will be parallel to the original pavement surface. Successive layers are placed in the same manner. Otherwise, the backfilling is performed in the same manner as described above. Figure 3-50 shows the correct way and the incorrect way to place AC backfill in a deep depression.

d. Full-depth patch. A full-depth patch normally extends to the subgrade.

(1) The edges of the patch should extend at least a foot into good pavement outside of the damaged area. The cut should be square or rectangular with the sides vertical. This is normally accomplished with a power saw or jackhammer. The area should then be thoroughly cleaned.

(2) If the subgrade is damaged, it should be repaired.

(3) Apply a light tack coat to the vertical face and allow it to become tacky. If the patch is placed

Figure 3-48. Hole to be patched with tack applied

Figure 3-49. Placing asphalt mix in patch.

on subgrade, no prime is needed; however, if it is placed on a granular base, it should be primed.

(4) For best results, the entire area should be filled with dense-graded hot-asphalt plant mix. The patch should be backfilled and compacted in 2 to 3 inch lifts. A rubber-tire or vibratory roller should be used whenever possible along with the hand-held compactors. Partial backfilling of the hole with compacted granular fill and topping with hot mix can be done when there is a shortage of hot mix. Cold mix can be used when necessary, but it is not encouraged.

e. *Pothole patching*. Potholes require proper preparation and backfill. All material for filling these holes must meet certain standards.

(1) Temporary repair of potholes may be made with premixed cold-laid AC or hot-mix bituminous concrete. To place this material during inclement weather, the pothole is cleaned out and dried using a pavement heater or blow torch. The hole is then

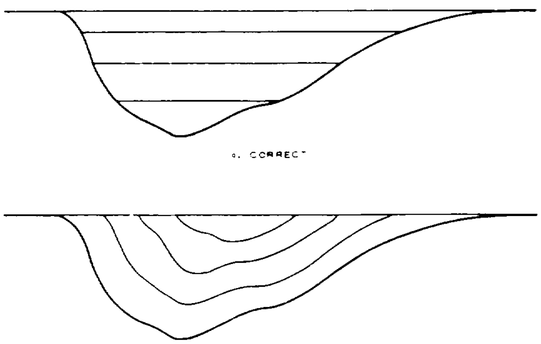

Figure 3-50. Placement of AC backfill in deep depression.

filled with the asphaltic material and compacted by hand tamp, mechanical tamper, roller, or loaded truck wheel. This temporary patch will be dislodged rather rapidly under traffic because the hole has not been properly prepared for a permanent patch.

(2) Permant repair of potholes requires proper preparation and backfill. First, the hole should be squared up and deepened to hard, firm base. This may be done with a pavement saw, air hammer, and chisel or by hand hammer and chisel. It is important that the sides be cut vertical and the bottom rest in hard firm soil or base. Base material should be replaced with equal or better material than that removed or with bituminous paving material. This material will be thoroughly compacted by use of mechanical or hand tamps. After backfilling with the base material, the hole will be primed with a light asphalt material such as RC-70 and allowed to cure until the asphalt becomes tacky. The prime may be applied with a paint brush. The last step is to replace the pavement surface material. If possible, the paving material should be a good quality hot-mix material. The hole will be overfilled approximately 40 percent of its pavement thickness to allow for compaction. This should give a smooth impervious surface. If cold-laid material is used, the patch may have a porous surface and requires a sand or fine aggregate seal coat for waterproofing (fig 3-51).

f. *Apply sand and remove*. This method is normally used where bleeding or flushing of asphalt has occurred. The repair is normally accomplished by placing hot sand or aggregate on the surface and embedding it by rolling. The surface will be cleaned of all loose debris or aggregate by brooming. When the surface is smooth, as on airfield areas, a natural sand is usually recommended. If most of the surface is rough and the bleeding is severe, a crushed sand should be used. If possible, the natural sand or crushed sand will be heated and placed on the area at a temperature of 275 degrees F or above.

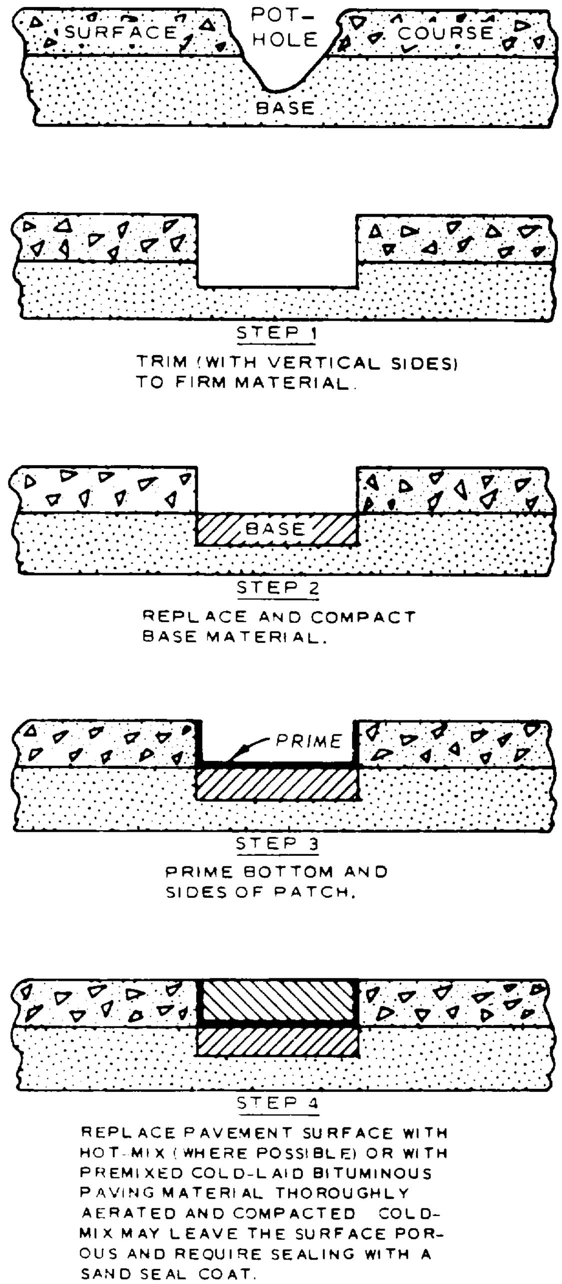

Figure 3-51. Permanent repair of potholes.

Spreading is usually done at the rate of 10 to 15 pounds per square yard. Spreading may be accomplished using spreader boxes, tailgate spreaders, or by hand where small areas are involved. After a section has been spread, a rubber-tired roller will be used immediately (about 2 minutes maximum) to seat the hot natural sand or crushed sand into the softened binder. After the surface has cooled, any loose material will be swept off. If necessary, the treatment may be repeated if the condition has not been permanently remedied.

g. *Surface treatments.* Surface treatments and materials are listed and discussed below.

(1) *Apply surface seal emulsion*. Surface seal (fog seal) can be a light application of asphalt or tar emulsion diluted with water. Most surface seals are used on sound plant-mix surfaces that have weathered, oxidized, fine cracks, and become brittle. When a diluted emulsion is used, it will flow into the fine cracks and form a thin coating on the pavement surface. After placing, the asphalt should cure until it is no longer tacky and then should be rolled with a rubber-tired roller. The kneading effect of the roller will aid in sealing the cracks. Asphalt emulsions surface seals may be placed at the minimum temperatures shown in TM 5-822-8/AFM 88-6, chapter 9 and NAVFAC DM-5. Care should be exercised in use of surface seals, and application should be in three or four increments; otherwise, there is a tendency on most of the surfaces for the seal material to make the surface slick, thus reducing the coefficient of friction. A cover aggregate will be used to prevent loss in surface friction. An application of medium curing asphalt emulsion can soften and enliven a weathered asphalt pavement surface. Rolling with a rubber-tired roller is also required to close the softened pavement surface. Before any surface seal is applied, the pavement surface will be thoroughly cleaned by rotary brooms, compressed air, or hand brooms. Any oil-softened areas will be removed and patched. Usually, the pavement surface should be dry and free of any loss debris; however, in the use of asphalt or tar emulsion, a slightly damp surface is beneficial.

(2) *Apply rejuvenator*. This method is used where the pavement surface is oxidized but not exhibiting any problems besides some possible light raveling and/or cracking. The rejuvenator is applied by a distributor truck with a spray bar (fig 3-52). The amount applied will depend on the condition and density of the pavement being rejuvenated. A normal range of application would be from 0.05 to .01 gallon per square yard. A small area should be selected for repair and sprayed with various rates in order to determine the amount repaired. This amount should be applied in two one-half coverages. Before spraying, the pavement should be swept and all loose material removed from the pavement. The pavement should be able to accommodate traffic within 24 hours. If too much is applied and it does not soak in, a slippery surface results, especially undesirable on airfields. It may be removed by applying sand to absorb the rejuvenator and then removing the sand. An adequate time frame, materials, and equipment should be allowed when appropriate.

(3) *Apply aggregate seal coat*. Sand and aggregate seal coats may be used to rejuvenate and seal the surface of weathered asphalt pavements and to seal porous asphalt pavement. These seals are constructed in the same manner as single-course bituminous treatments. The selected bituminous material is applied at the rate of 0.01 to 0.4 gallon per square yard, depending on the aggregate size and condition of the surface to which it is being applied. The bitumen will be applied at the temperature recommended for the selected material. Details of design and application temperatures may be found

Figure 3-52. Applying rejuvenator

in TM 5-228/AFM 88-6, chapter 9 or NAVFAC DM-5.

(4) *Slurry seals.* A slurry seal is a mixture of asphalt emulsion, crushed fine aggregate (1/8 to ¼ inch), mineral filler, and water. The materials are combined in proportions to produce a mixture of slurry consistency and applied to the pavement surface. Before application, the pavement surface will be thoroughly cleaned by brooming or compressed air. If the pavement surface is saturated with oil or grease, it cannot be satisfactory cleaned for slurry application. These areas must be replaced if a satisfactory bond between slurry and pavement surface is to be obtained. After the seal has set sufficiently to resist pickup, rolling it with a rubber-tired roller will give best results. Slurry seals require no heating, but best results are obtained when they are applied at an ambient temperature of 60 degrees F or higher. Slurry seals will not be used where traffic is heavy because they wear off quickly.

h. *Fuel resistant seal or overlay*. When continuous fuel spillage occurs on an asphalt surface, the binder becomes soft and is frequently leached away. This results in raveling of the surface aggregate and increased pavement deterioration. Kerosene, hydraulic fluid, jet fuel, oil, gasoline, and other such petroleum products are the main offenders. Tarrubber which has been used in spillage areas in the past is no longer available due to environmental concerns. Tar which is derived from coal rather than petroleum is only moderately affected by petroleum products. Tar products such as coal tar emulsion or tar concrete will be used in moderate fuel spillage areas. If areas are subject to severe fuel spillage, replacement of the area with PCC will be required. Areas subject to only occasional fuel spillage will usually heal without repair and only minor damage will result. All fuel spills should be immediately washed down with low pressure water.

i. Porous friction surface. A PFC is used to provide an increase in skid resistance and reduce hydroplaning on pavement surfaces.

(1) PFC requirements are given in TM 5922-8/AFM 88-6, chapter 9, and NAVFAC DM-5.

(2) The hot-mix PFC material will be spread and seated with a steel-wheel roller (normally 10 to 12 tons). No density is required; only the seating of the aggregate is required.

(3) If raveling occurs, it can be controlled by applying a light spray of asphalt emulsion to hold the aggregate in place and not close the voids.

(4) Sealing cracks across a PFC will reduce the PFC's internal drainage but will not greatly decrease the PFC's effectiveness.

(5) To repair a damaged PFC, all the damaged material must be removed and, if necessary, the underlying pavement repaired. The area is then cleaned and a light tack coat applied. The edges of the PFC should not receive any tack as this would seal the voids in the pavements.

(5) Delamination occurs when the PFC fails to bond to the underlying pavement. This can cause failure of the PFC under traffic.

(7) Rubber deposits or buildup are critical on a PFC as they decrease the PFC's effectiveness to provide skid resistance. There is no fully successful method to remove rubber deposits as most commonly used methods for removal will damage the PFC.

(8) Fuel spills on a PFC should be flushed with water as soon as possible. Care must be taken to not damage the PFC with high pressure water application, but the water should be allowed to flow onto the affected area. If the damage warrants, the affected PFC should be removed and replaced.